Intended for
Arnold & Porter Kaye Scholer LLP

Document type
Expert Report

Date
December 8, 2023

Project Number
1690026499

EXPERT REPORT OF SHARI BETH LIBICKI, PH.D.

HONEYWELL METROPOLIS WORKS

Shari Beth Libicki, Ph.D.

Exhibit
Steward et al v Hineywell et al
Dr. Shari Libicki
0265

EXPERT REPORT OF SHARI BETH LIBICKI, PH.D.
HONEYWELL METROPOLIS WORKS

Project name	**Expert Report of Shari Beth Libicki, Ph.D., in the Matter of Honeywell Metropolis Works** **ROGER STEWARD, ET AL., Illinois residents, on behalf of themselves individually and all others similarly situated, Plaintiffs,** **v.** **HONEYWELL INTERNATIONAL, INC. Defendant.** **Case No.: 3:18-cv-01124-SMY** **CITY OF METROPOLIS, ILLINOIS, a Municipal Corporation, and COUNTY OF MASSAC, a Municipal Corporation. Plaintiffs,** **v.** **HONEYWELL INTERNATIONAL, INC. Defendant.** **Case No. 3:21-cv-00860** **SHANNON DASSING, individually and as executrix of STEPHEN KRUEGER, decedent. Plaintiff,** **v.** **HONEYWELL INTERNATIONAL INC. Defendant.** **Consolidated Case No. 3:21-cv-00485-SMY**
Project no.	**1690026499**
Recipient	**Arnold & Porter Kaye Scholer LLP**
Document type	**Expert Report**
Date	**December 8, 2023**
Prepared by	**Shari Beth Libicki, Ph.D.**

CONTENTS

1.	**Introduction and Scope of Work**	**1**
2.	**Summary of Opinions**	**2**
2.1	Air Monitoring for Emissions from the MTW Facility is Robust and Reliable	2
2.2	The MTW Air Monitoring Program Has Broad Spatial and Temporal Coverage	2
2.3	My AERMOD Model Reliably (and Conservatively) Predicts Observed Air Concentrations	2
2.4	The Nearest Resident (NR-7) Is the Most Exposed Residential/Offsite Location	2
2.5	Airborne Concentrations and Deposition of Radionuclides Decrease Rapidly with Distance from MTW	2
2.6	Dr. Auberle's Modeling Contains Errors, But His Overall Results Are Reasonable and Consistent With My Modeling	3
2.7	The Proposed Class Members Are Not Similarly Situated	3
3.	**Description of the Site and Uranium Processing**	**4**
3.1	Site Location and Property Description	4
3.1.1	Site Use Over Time	8
3.1.2	Description of Buffer Zones	8
3.1.3	Description of Vegetation	9
3.1.4	Change in Land Use and Surface Characteristics Over Time	10
3.1.5	Nearby Meteorology	12
3.2	MTW Uranium Operations	13
3.2.1	Description of MTW Operations	13
3.2.2	MTW Historical and Current Annual Production	15
3.3	Emissions from MTW	16
3.3.1	Chemical Species Typically Released from MTW	16
3.3.2	Methods for Estimating Emissions from MTW	16
3.3.3	Emissions Inventory for MTW	17
3.4	Ambient Air at and Near the Site	19
3.4.1	Background Concentrations	19
3.5	Ambient Air Monitoring	19
3.5.1	Description of Facility Monitoring Program	19
3.5.2	Description of IEMA Monitoring Program	20
4.	**Air Dispersion Modeling of Uranium Emissions from MTW**	**22**
4.1	Current Methods for Modeling Air Dispersion from the Site	22
4.2	AERMOD Dispersion Model	22
4.3	Modeling Setup	23
4.3.1	Dispersion Model Selection and Application	23
4.3.2	Meteorological Data	23
4.3.3	Emissions and Averaging Periods	24
4.3.4	Stack Parameters	25
4.3.5	Building Downwash	27
4.3.6	Receptors	27
4.3.7	Land Use and Precipitation Analysis	28
4.4	Results of Modeling Emissions from MTW	29
4.5	Comparison of Air Modeling to Air Monitoring	32
5.	**Affirmative Opinions**	**34**
5.1	Air Monitoring is Robust and Reliable	34
5.1.1	Air Monitoring Program has Broad Spatial and Temporal Coverage	34

5.2	IEMA Air Monitoring is Independent of MTW	34
5.3	Air Monitoring Data Indicate that Concentrations of Radionuclides Decrease Rapidly with Distance from MTW	34
5.3.1	Air Monitoring Data has Detected Unplanned Releases	36
5.4	The Decrease in Measured Concentrations with Distance is Consistent with Modeled Concentrations that One Would Expect if Emissions were from MTW	36
5.5	Nearest Resident is the Most Exposed Residential/Offsite Location	37
5.6	Air Dispersion Model is Reliable and Conservative	37
6.	**Review of Dr. Auberle's Opinions**	**38**
6.1	Dr. Auberle's Air Dispersion Modeling	38
6.1.1	Dr. Auberle's Modeling Source Parameters and Locations	38
6.1.2	Dr. Auberle's Meteorological Data	39
6.1.3	Dr. Auberle's Emissions	42
6.1.4	Comparison of Modeling Results	43
6.1.5	Conservative Nature of Modeling	43
7.	**Alternative Sources of Emissions**	**45**
7.1	Paducah Gaseous Diffusion Plant	45
7.2	Coal-Fired Power Plants	48
7.3	Cook Coal Terminal	50
7.4	Orano TLI UF_6 Cylinder Service Center	50
7.5	Other Anthropogenic and Natural Sources of Uranium	51
7.6	Other Sources of Alpha Radiation	52
7.6.1	Radon	52
7.6.2	Thorium	54
8.	**The Class is Not Similarly Situated**	**55**
8.1	Proximity to Different Sources Matters	55
8.2	Effect of Vegetation	55
8.3	Housing Construction and Age	56
8.4	Impacts Are Not Distributed Uniformly	56
8.5	The Exposure of Each Individual Must be Assessed Individually	59

TABLE OF TABLES

Table 6-1: Summary of calm hours in Dr. Auberle's meteorological files

TABLE OF FIGURES

Figure 3-1: MTW site location
Figure 3-2: Aerial photograph of the area surrounding MTW
Figure 3-3: Facility layout
Figure 3-4: Buffer zone around MTW
Figure 3-5: 2021 tree canopy
Figure 3-6: Change in tree canopy cover between 2011 and 2021
Figure 3-7: Change in impervious descriptor between 2001 and 2021
Figure 3-8a: Wind rose for 2017-2021 at Metropolis Municipal Airport (KM30)
Figure 3-8b: Wind rose for 2017-2021 at Paducah Airport (KPAH)
Figure 3-9: Flow schematic of UF_6 production process at MTW
Figure 3-10: Historical annual production capacity
Figure 3-11: Facility-wide uranium emissions
Figure 3-12: Location of MTW ambient air monitoring stations
Figure 3-13: Location of IEMA monitoring stations
Figure 4-1: Modeled average uranium activity concentration in the area surrounding MTW
Figure 4-2: Modeled cumulative uranium deposition in the area surrounding MTW
Figure 4-3: Distributions of modeled to monitored uranium concentrations at MTW's offsite monitor locations
Figure 5-1: Ambient air concentrations of uranium near MTW based on long-term MTW data (1998-2018)
Figure 5-2: Ambient air total alpha activity concentration based on long-term IEMA data (1996-2013)
Figure 6-1: Wind roses based on Dr. Auberle's meteorological data for 1975-1979 (top) and 2014-2018 (bottom)
Figure 6-2: Comparison of Dr. Auberle's modeling to monitored uranium activity concentrations
Figure 7-1: Paducah site location
Figure 7-2: Location of TVA Shawnee Power Plant
Figure 7-3: Location of Joppa Steam Power Plant
Figure 7-4: Location of Cook Coal Terminal
Figure 7-5: Location of Orano TLI UF6 Cylinder Service Center
Figure 7-6: Geologic indoor radon potential in Illinois (top) and Kentucky (bottom)
Figure 7-7: Hicks Dome location and airborne radiometric map
Figure 8-1: Long-term average modeled concentration ($x10^{-14}$ microcuries per milliliter) at twelve residences randomly chosen within the proposed Class Area
Figure 8-2: Long-term cumulative total deposition (milligrams per square meter) at twelve residences randomly chosen within the proposed Class Area

APPENDICES

Appendix A
Curriculum Vitae
Appendix B
Expert Testimony in the Past Four Years

Appendix C
References and Materials Considered
Appendix D
MTW Litigation Soil Database
Appendix E
MTW Environmental Litigation Database
Appendix F
Modeled Uranium Concentration and Deposition at Plaintiff Locations
Appendix G
Modeled Uranium Concentration and Deposition at NR-7

Acronyms and Abbreviations

ADMS	Atmospheric Dispersion Modeling System
ASOS	Automated Surface Observing System
AERMOD	AMS/EPA Regulatory Model
AWOS	Automated Weather Observing System
BPIP	Building Profile Input Program
BSE	Bachelor of Science in Engineering
CAP88	Clean Air Act Assessment Package - 1988
CaF_2	calcium fluoride
CAMx	Comprehensive Air Quality Model with Extensions
CFR	Code of Federal Regulations
CH_4	methane
Ci	curie
CMAQ	Community Multiscale Air Quality Model
CO	carbon monoxide
CO_2	carbon dioxide
DOE	Department of Energy
DOJ	Department of Justice
DUF_6	depleted uranium hexafluoride
EPA	U.S. Environmental Protection Agency
EROS	Earth Resources Observation and Science
°F	Fahrenheit
FFA	Federal Facility Agreement
FMB	Feed Materials Building
F_2	fluoride
ft	feet
g	gram
GSL	Global Systems Laboratory
H_2	hydrogen
HAP	hazardous air pollutant
HF	hydrogen fluoride
H_2SO_4	sulfuric acid
IEMA	Illinois Emergency Management Agency and Office of Homeland Security

IF_5	iodine pentafluoride
ISCST	Industrial Source Complex-Short Term, Version 3
ISD	Integrated Surface Database
KDEP	Kentucky Department for Environmental Protection
KF	potassium fluoride
kg	kilogram
km	kilometer
KOH	potassium hydroxide
m	meter
m^2	square meter
m^3	cubic meter
m/s	meters per second
MSE	Master of Science in Engineering
MTW	Honeywell Metropolis Works Facility
MW	megawatt
NCEI	National Centers for Environmental Information
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NO_x	nitrogen oxides
NR	nearest resident
NRC	U.S. Nuclear Regulatory Commission
NWS	National Weather Service
ppm	parts per million
PGDP	Paducah Gaseous Diffusion Plant
PM	particulate matter
Ra-226	radium-226
SbF_6	antimony pentafluoride
SCIPUFF	Second-Order Closure Integrated Puff Model
SF_6	sulfur hexafluoride
SO_2	sulfur dioxide
SOP	standard operating procedure
SWAPE	Soil / Water / Air Protection Enterprise
Th-230	thorium-230

ThO_2	thorium dioxide
TVA	Tennessee Valley Authority
U	uranium
U-234	uranium-234
U-235	uranium-235
U-238	uranium-238
UCSC	UF_6 Cylinder Service Center
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium oxide
U_3O_8	triuranium octoxide
UMWA	United Mine Workers of America
US	United States
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VOM	volatile organic material
WISE	World Information Service on Energy
µCi/ml	microcuries per milliliter
$\mu g/m^2$	micrograms per square meter

1. INTRODUCTION AND SCOPE OF WORK

Since 1989, I have worked at Ramboll, previously ENVIRON International Corporation, an international scientific and engineering consultancy, applying scientific theories and chemical engineering principles of mass transport to air emissions estimation and transport. I have been a Principal at Ramboll since 1995. While at Ramboll, I have conducted numerous studies on the generation, fate and transport of airborne emissions, including performing air dispersion and deposition modeling. I have designed and operated air monitoring systems and analyzed data from those monitoring systems. I have completed emissions inventories for a wide variety of chemical and other industry sectors, including historical inventories. I currently serve as a senior member of Ramboll's air practice, and I am leading sustainability integration for Ramboll's Environment and Health Division. I earned a PhD in Chemical Engineering from Stanford University and a BSE and an MSE in Chemical Engineering from the University of Michigan. In addition to my work at Ramboll, I am an Adjunct Professor in the Department of Chemical Engineering at Stanford University. I also have served on several scientific advisory and technical working groups. My curriculum vitae is attached as **Appendix A** to this report.

Attached as **Appendix B** is a list of cases in which I have served as a testifying expert during the last four years. Ramboll is being paid for my services at my standard rate of $470 per hour. Neither Ramboll's nor my compensation in this matter is dependent on the opinions I provide or the outcome of this litigation.

I have been asked to evaluate the airborne fate and transport (including emissions, dispersion, deposition, and air monitoring) of alpha radiation from the Honeywell Metropolis Works Facility (MTW). I have also been asked to review and analyze the September 2023 expert report of Dr. William Auberle, as it pertains to these issues. This report contains my opinions in the litigation. This evaluation is based on my visit to MTW in December 2022; discussions with MTW personnel; my review of MTW data; monitoring information provided by MTW, the Plaintiffs, and government records and other engineering and technical information; and also includes information cited in this report. This report is based on my education and expertise, the scientific literature, and the materials that I have reviewed for this case. My opinions are being offered to a reasonable degree of engineering and technical certainty. I reserve the right to supplement this report and my opinions should I review new information.

2. SUMMARY OF OPINIONS

This section contains a summary of my opinions. These opinions are briefly described here and supported in the balance of the report.

2.1 Air Monitoring for Emissions from the MTW Facility is Robust and Reliable

The air monitoring data for the MTW Facility is robust and reliable. Since 1977, MTW has operated continuous air monitors at four points along the restricted area fence line, two on-site locations in the prevailing wind direction, one offsite location approximately one mile downwind of the MTW Facility, and one point at the location of the nearest residence (NR-7). In addition, the State of Illinois, through the Illinois Emergency Management Agency (IEMA), conducts air monitoring that is independent of MTW's monitoring to ensure that the public is not being exposed to potentially harmful levels of ionizing radiation. The MTW and IEMA monitoring cover extensive ground both around MTW and within Metropolis and provide confidence that airborne emissions of radionuclides from MTW (including from unplanned releases and fugitive sources of emissions) are captured in the air monitoring data.

2.2 The MTW Air Monitoring Program Has Broad Spatial and Temporal Coverage

The combination of MTW and IEMA air monitoring provides broad spatial and temporal coverage. The MTW monitoring program includes monitors close to the Facility and in the direction of the prevailing winds while the IEMA monitoring provides monitoring data throughout Metropolis. This combination of multiple monitors with broad spatial coverage provides insight on radioactivity concentration patterns. In addition, the extended time range over which monitoring has been conducted (which covers the majority of MTW's operational history) provides insight into how radioactivity patterns have changed over time.

2.3 My AERMOD Model Reliably (and Conservatively) Predicts Observed Air Concentrations

Air dispersion modeling was conducted at my direction using AERMOD (a model created by the United States Environmental Protection Agency) to estimate ambient air concentrations of uranium-based radiation from MTW at various locations in the Metropolis community. The modeled values correlate well with the monitored values observed at the two offsite monitoring locations and generally overstate actual measured concentrations. This demonstrates that the model is reliably (and conservatively as discussed in Section 5.6 below) predicting observed concentrations and increases confidence in the model results.

2.4 The Nearest Resident (NR-7) Is the Most Exposed Residential/Offsite Location

The nearest resident (i.e., NR-7) is the residential/offsite location that is most exposed from airborne radiological emissions from the MTW Facility. This opinion is based on monitoring data, modeling results, and prevailing winds. As noted in Section 3.5, both MTW and IEMA measure their highest offsite readings at NR-7. In addition, the AERMOD modeling discussed in Section 4 shows that the highest residential offsite impacts occur near NR-7, with offsite air concentrations and deposition decreasing rapidly with distance from MTW.

2.5 Airborne Concentrations and Deposition of Radionuclides Decrease Rapidly with Distance from MTW

Both the air monitoring and the air dispersion and deposition modeling show a consistent pattern with radiological activity concentration decreasing with distance from MTW. Specifically, MTW air

monitoring shows uranium activity concentrations decreasing with distance from MTW, and IEMA air monitoring shows alpha activity concentrations decreasing with distance from MTW. The air dispersion and deposition modeling results follow this same pattern.

2.6 Dr. Auberle's Modeling Contains Errors, But His Overall Results Are Reasonable and Consistent With My Modeling

As noted in Section 6 of this report, Dr. Auberle's modeling contains numerous errors. However, because the errors contained in Dr. Auberle's model tend to both understate and overstate emissions and dispersion, they do not impact the overall results significantly. In fact, Dr. Auberle's resulting deposition is somewhat lower than I modeled, likely due to the errors that I point out in this report. However, his modeling shows the same trends that my modeling shows, which provides increased confidence in the overall modeling results.

2.7 The Proposed Class Members Are Not Similarly Situated

The AERMOD modeling results show that properties located within the proposed Class Area were exposed to dramatically different levels of air emissions and deposition depending on their proximity to the MTW Facility and location relative to the Facility based on the prevailing wind direction. Thus, for example, a property located 2.5 miles upwind from the Facility would experience very different levels of exposure than a property located 0.5 miles downwind from the Facility (and in almost all cases, the modeled values are a fraction of the levels at NR-7).

3. DESCRIPTION OF THE SITE AND URANIUM PROCESSING

MTW is currently the sole uranium hexafluoride (UF_6) conversion facility in the United States and is therefore a critical supplier for domestic energy production and commercial medical devices.[1]

3.1 Site Location and Property Description

MTW, owned by Honeywell International Inc. (Honeywell) and operated by Honeywell's Specialty Materials division, is located at 2768 North U.S. Highway 45 in Metropolis, Illinois (**Figure 3-1**). The Facility is located in Massac County, which can be characterized as a predominantly rural area with low population density. MTW sits on a 1,100-acre site (under 60 acres within the fence-line). The Ohio River borders the Facility to the south. As shown in **Figure 3-2**, active operations are located near the center of the site, which is surrounded by land that is predominantly forested and currently owned by Honeywell. **Figure 3-3** shows the general site layout at MTW.

[1] Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.

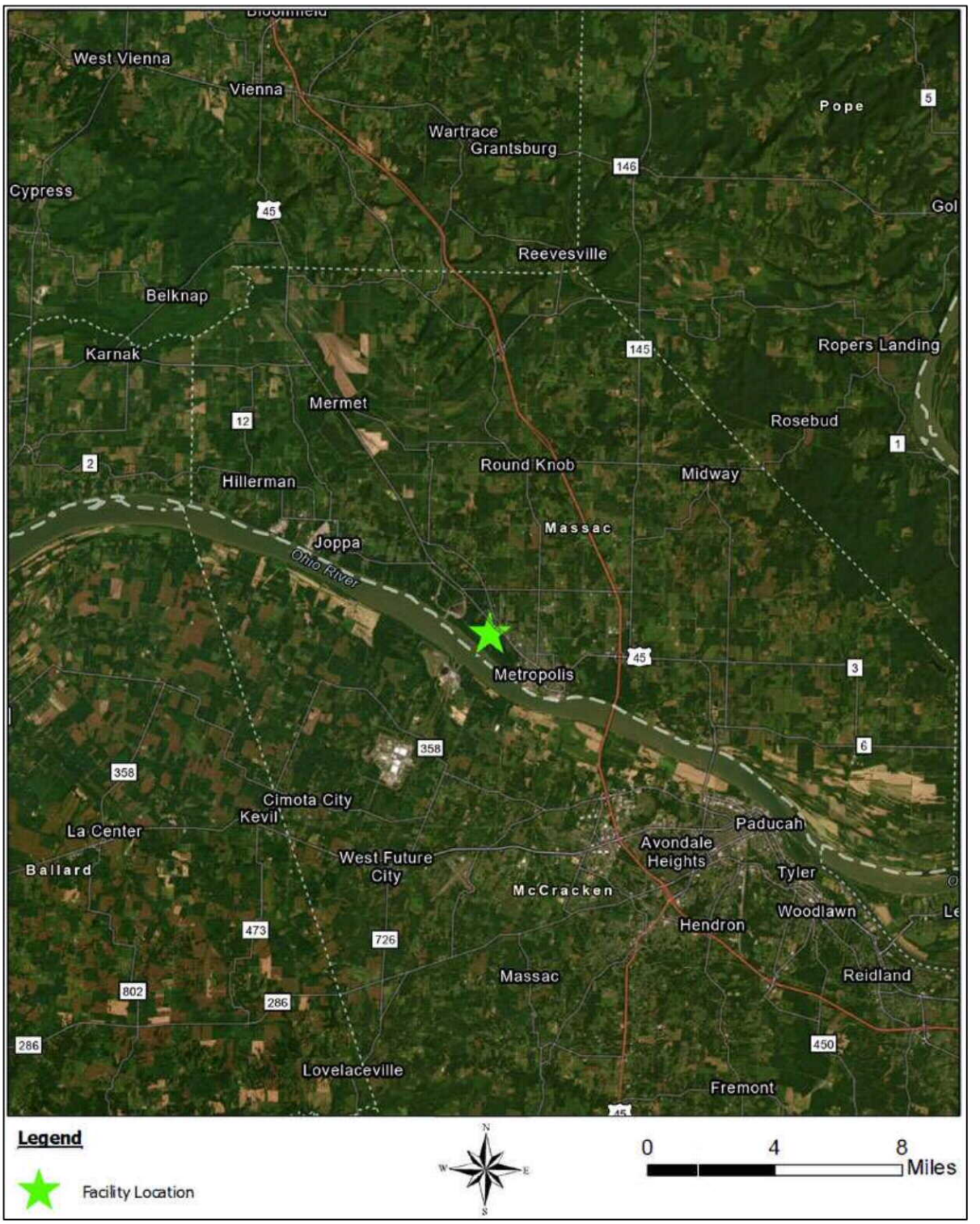

Figure 3-1: MTW site location[2]

[2] Ibid.

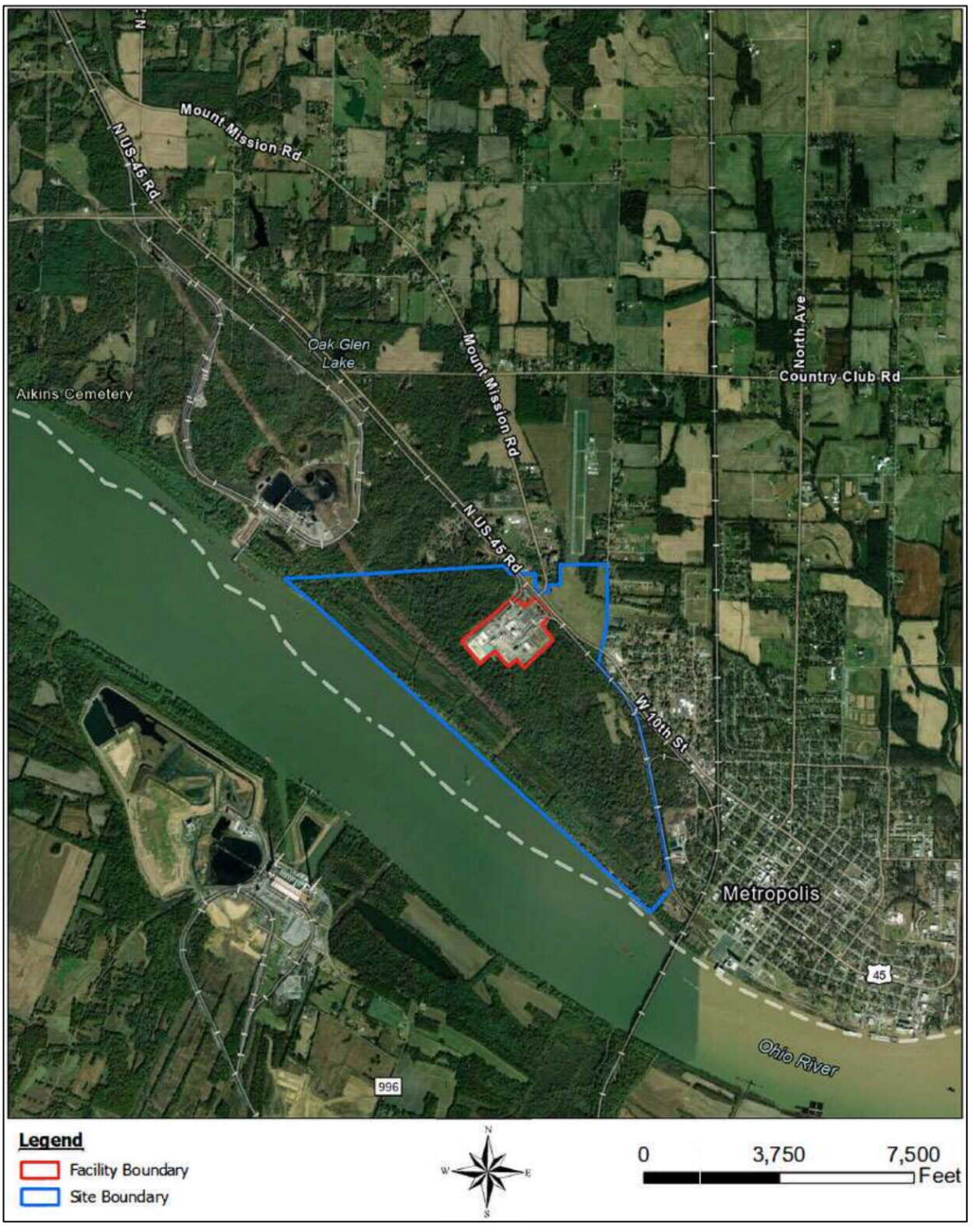

Figure 3-2: Aerial photograph of area surrounding MTW

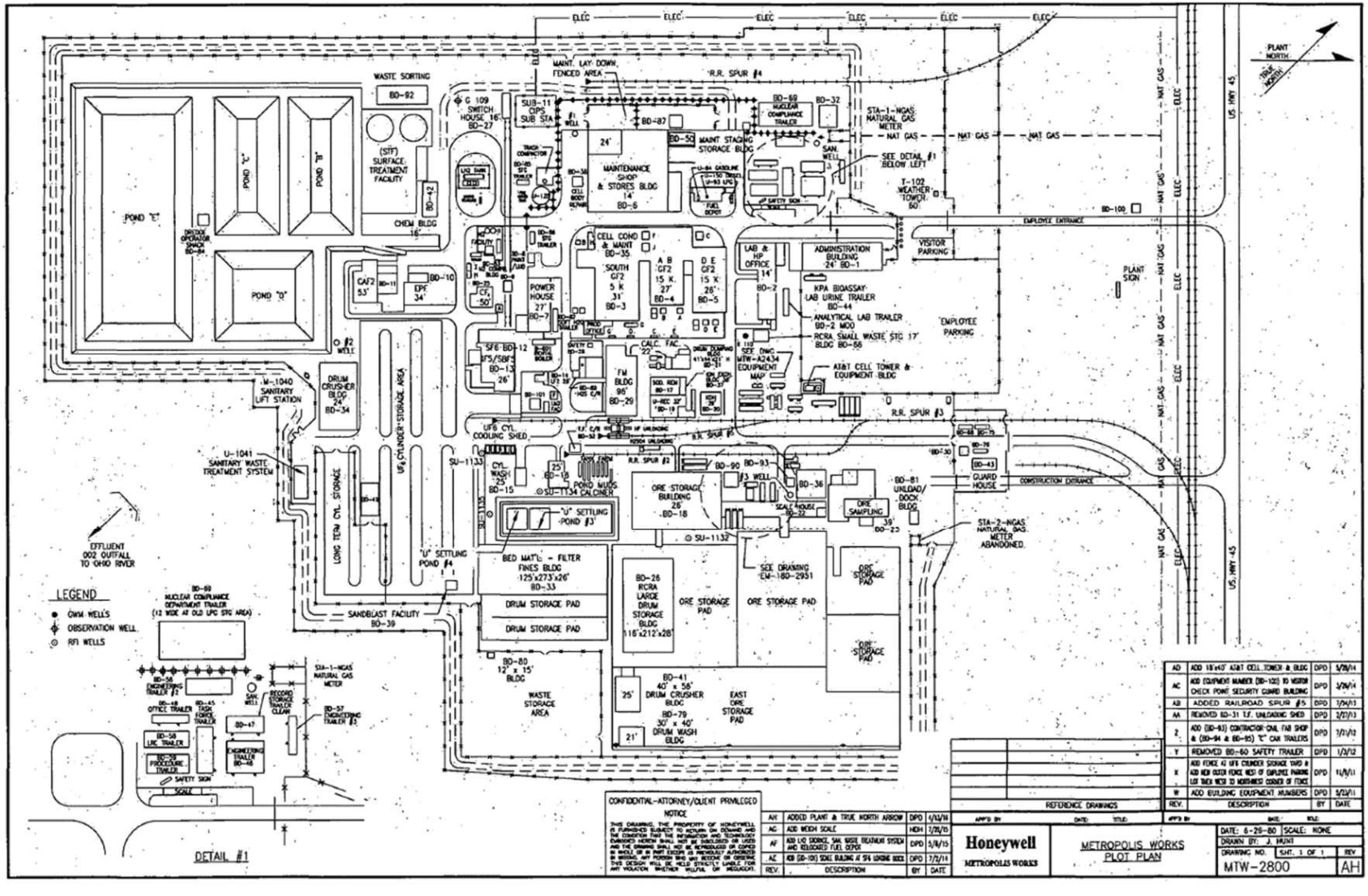

Figure 3-3: Facility layout[3]

[3] Ibid.

Case 3:18-cv-01124-SMY Document 302-4 Filed 06/27/24 Page 16 of 94 Page ID #77111

3.1.1 Site Use Over Time

Construction of MTW was completed in 1958, and under a U.S. Atomic Energy Commission contract, MTW began UF_6 production in 1959 under the ownership of Allied-Signal, Inc.[4] MTW was originally built to supply UF_6 to the Paducah Gaseous Diffusion Plant (PGDP). MTW ceased operations from 1964 until 1968. Since 1968, MTW has operated as a private conversion facility to provide UF_6 to various uranium enrichment facilities.[5]

Honeywell is authorized to possess 150 million pounds of natural uranium for its work chemically converting the ore concentrates into UF_6.[6] MTW manufactures fluorine products including UF_6 for nuclear fuel, sulfur hexafluoride (SF_6) for electric utilities, and iodine pentafluoride (IF_5) and antimony pentafluoride (SbF_5) for stain and water resistance. About 80 percent of the plant's work involves refining raw uranium ore concentrate into UF_6.[7]

MTW has undergone startups and shutdowns since it began production in in 1959. Between 1964 and 1967, MTW was in a ready-idle state, until it resumed operations again in 1968 under license number SUB-256.[8] MTW was shut down on December 22, 2003, and resumed operations on March 27, 2004, when the Nuclear Regulatory Commission (NRC) authorized Honeywell to resume ore preparation.[9] MTW entered a ready-idle state again in 2018 and resumed operation in 2023.[10]

Since beginning operations, MTW's production capacity has been increased through several license renewal applications submitted to the NRC. Presently, Honeywell is permitted to produce 15,000 metric tons of UF_6 annually.[11] The uranium ore concentrate used as feed is approximately 75 percent uranium by weight, and the produced UF_6 contains less than 300 parts per million (ppm) by weight of residual compounds.[12]

3.1.2 Description of Buffer Zones

The manufacturing area of approximately 57 acres is centrally located within the property boundary while the remainder of the area consists of forests, vacant grasslands, and agricultural fields. Within the properties owned by Honeywell, the "green buffer" is at its smallest on the northeast side of the property with about 250 meters of grassland and agricultural field area separating the manufacturing area and the nearest residential parcel. The greatest extent of the "green buffer" is approximately 2.3 kilometers (km) to the southeast. This is shown graphically in **Figure 3-4**.

[4] Ibid.
[5] Ibid.
[6] United States Nuclear Regulatory Commission (US NRC). 2021. Honeywell Metropolis Works – U. S. Nuclear Regulatory Commission Integrated Inspection Report Number 40-3392/2021-003. Available at: https://www.nrc.gov/docs/ML2129/ML21292A183.pdf. Accessed November 13, 2023.
[7] GlobalSecurity.org. Honeywell Specialty Materials. Available at: https://www.globalsecurity.org/wmd/facility/metropolis.htm. Accessed December 7, 2023.
[8] United States Nuclear Regulatory Commission (US NRC). 2021. Honeywell Metropolis Works – U. S. Nuclear Regulatory Commission Integrated Inspection Report Number 40-3392/2021-003. Available at: https://www.nrc.gov/docs/ML2129/ML21292A183.pdf. Accessed November 13, 2023.
[9] Ibid.
[10] Honeywell. 2018. Honeywell Metropolis Works "Ready Idle" Status. Available at: https://www.nrc.gov/docs/ML1802/ML18023A384.pdf. Accessed November 13, 2023.
[11] Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.
[12] Ibid.

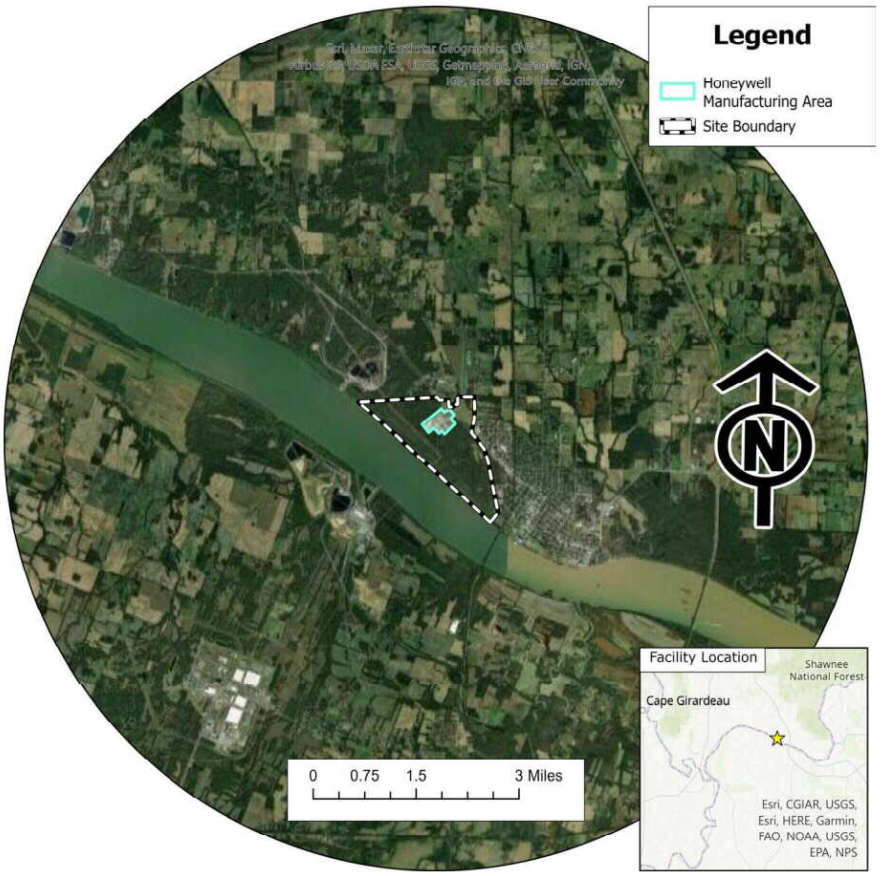

Figure 3-4: Buffer zone around MTW

3.1.3 Description of Vegetation

The area surrounding the site includes farmland, forest, a conservation area, private residences, and some industrial and commercial use properties. Vegetation in the immediate surrounding area is predominantly forest with a mix of cultivated crops and residential areas to the north, the Ohio River to the south, and the City of Metropolis to the east. **Figure 3-5** shows the percentage of tree canopy around the site based on tree canopy data from 2021. In the immediate vicinity of MTW, the highest density of canopy can be seen northwest and southeast of MTW and includes forested areas both inside and outside the MTW property boundary.

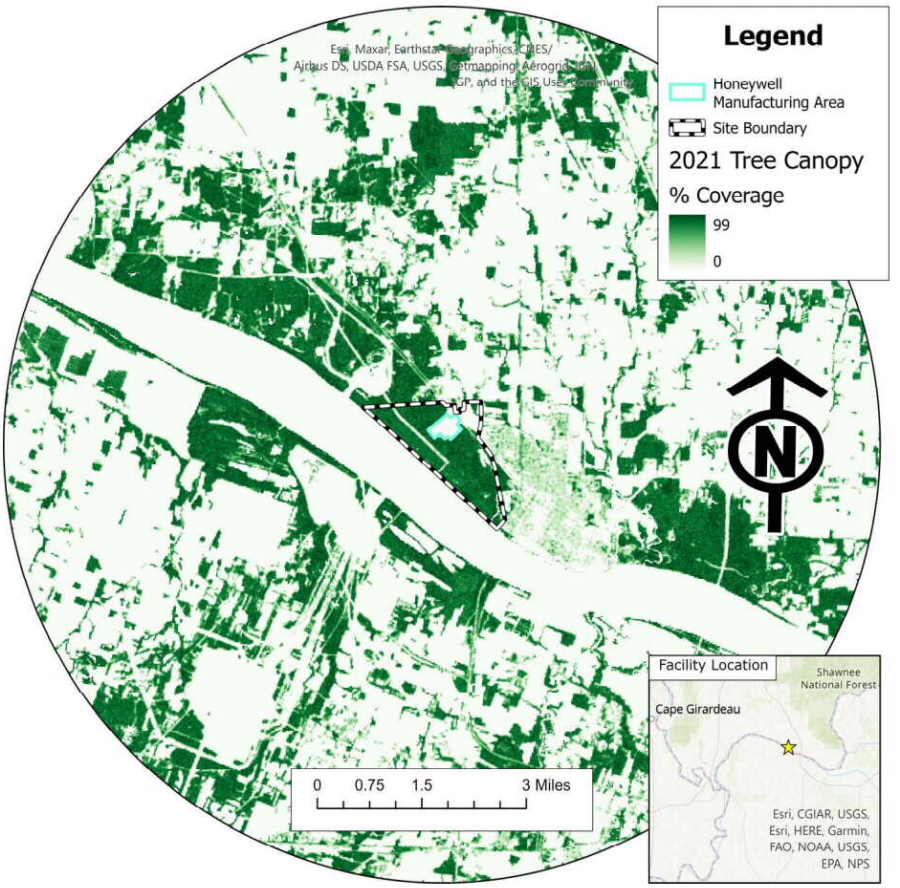

Figure 3-5: 2021 tree canopy[13]

3.1.4 Change in Land Use and Surface Characteristics Over Time

Surface characteristics, such as the amount of tree canopy cover and the imperviousness of the ground surface, impact the dispersion of air contaminants and the mechanisms that drive their partitioning into different media such as groundwater and soil. A change in surface characteristics can change the air dispersion. Surfaces with obstructions to air flow such as forests and urbanized areas create turbulence which widens airborne plumes, while smoother surfaces such as open fields and paved areas create little turbulence and are associated with narrower but more concentrated plumes. In addition, vegetation can reduce particulate concentration through adsorption of particulate matter. **Figure 3-6** shows the percent change in tree canopy cover between 2011 and 2021 near MTW, with green areas representing the areas where the canopy cover increased and purple areas representing the areas where the canopy cover decreased. The overall trend over the 11-year period shows a decrease in tree canopy along the riverfront, including the Facility, and mixed changes elsewhere.

[13] Earth Resources Observation and Science (EROS) Center, 2003-2023. National Land Cover Database (NLCD) 2001-2021 Products, Data Release. Available at: https://www.mrlc.gov/viewer/. Accessed October 25, 2023.

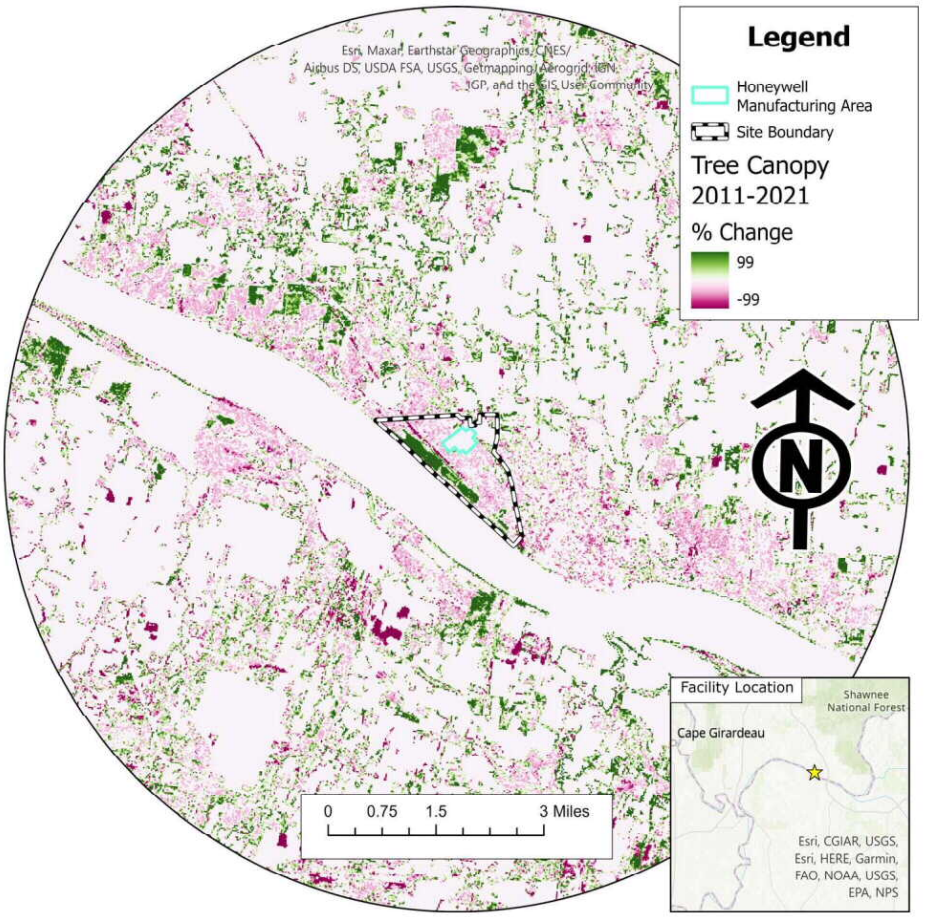

Figure 3-6: Change in tree canopy cover between 2011 and 2021[14]

The porosity of surfaces can also affect the fate of deposited airborne contaminants. In general, a nonporous surface would be more resistant to uptake, while greater uptake would be expected as porosity increases. **Figure 3-7** shows the percent change in impervious cover between 2001 and 2021, with green representing areas with increased impervious coverage and red representing the locations with decreased impervious coverage. While there is little increase in imperviousness, there were also no areas where imperviousness decreased. This is consistent with the area's slowly declining population. Impervious cover changed little over the 21-year period. I was unable to locate data prior to 2001.

[14] Ibid.

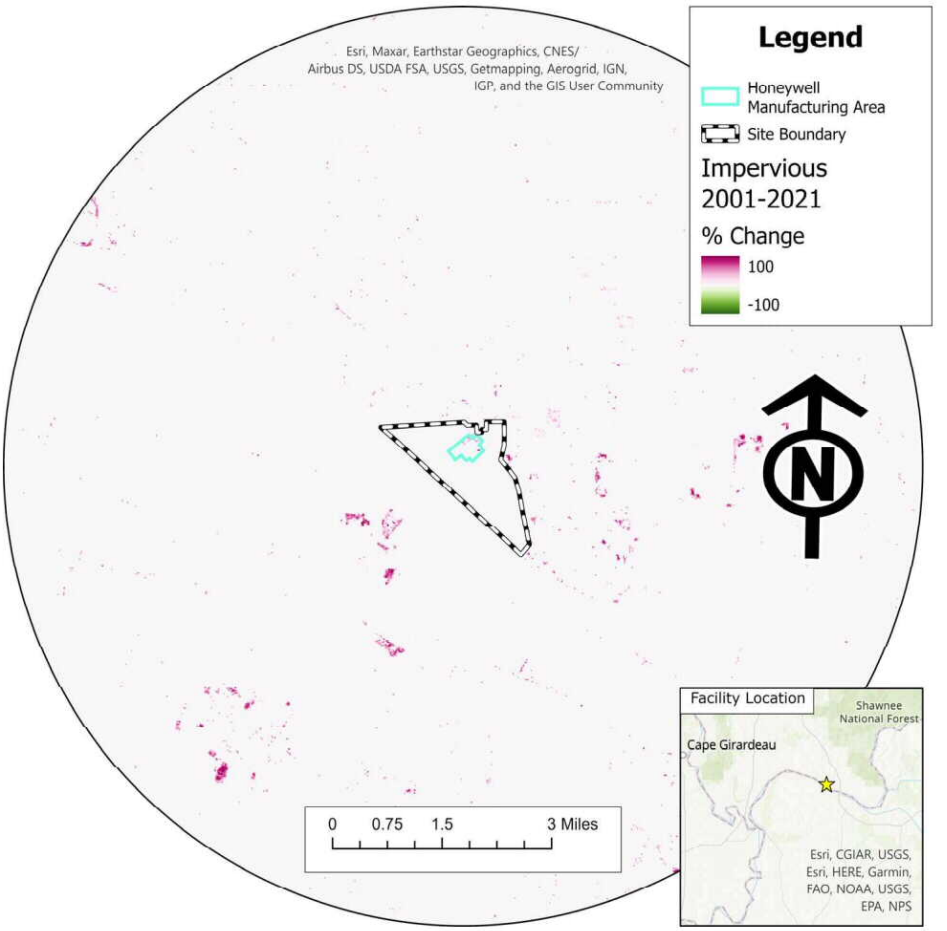

Figure 3-7: Change in impervious descriptor between 2001 and 2021[15]

3.1.5 Nearby Meteorology

MTW is located in the City of Metropolis, which is characterized by a humid continental climate with hot summers and cold winters. The average high temperature reaches into the mid-90s °F during July and August, while the average low temperature falls to the teens and twenties °F in January. Metropolis receives about 48 inches of rain and 8 inches of snow per year, with precipitation occurring over 108 days.[16]

The closest public meteorological stations are at the Metropolis Municipal Airport (Metropolis Airport) and the nearby Barkley Regional Airport (Paducah Airport). Wind roses (i.e., diagrams showing the frequency distribution of wind speeds and wind directions) for both airports can be seen in **Figure 3-8**. The Metropolis Airport is noteworthy for its low data capture. In a recent five-year period (2017-2021), there were 9,593 hours out of 43,824 hours total where at least one required parameter for air dispersion modeling was missing from the Metropolis Airport meteorological record, including no meteorological data from September 18, 2020 to April 29, 2021. In contrast, for the same five-year period at Paducah Airport, there were only 131 hours where at least one required parameter for air dispersion modeling was missing. It is also

[15] Ibid.
[16] Climate Data. Metropolis Climate. Available at: https://en.climate-data.org/north-america/united-states-of-america/illinois/metropolis-132997/. Accessed October 25, 2023.

important to note that 1-minute interval wind data is available at Paducah Airport but not at Metropolis Airport. At Metropolis Airport, wind speeds below 1.5 meters per second (m/s) are treated as calm, whereas at Paducah Airport, only winds below 0.5 m/s are treated as calm. These differences have critical implications for air dispersion modeling, since the model is unable to calculate concentration and deposition for hours where the wind is classified as calm. This is further discussed in Section 4 below.

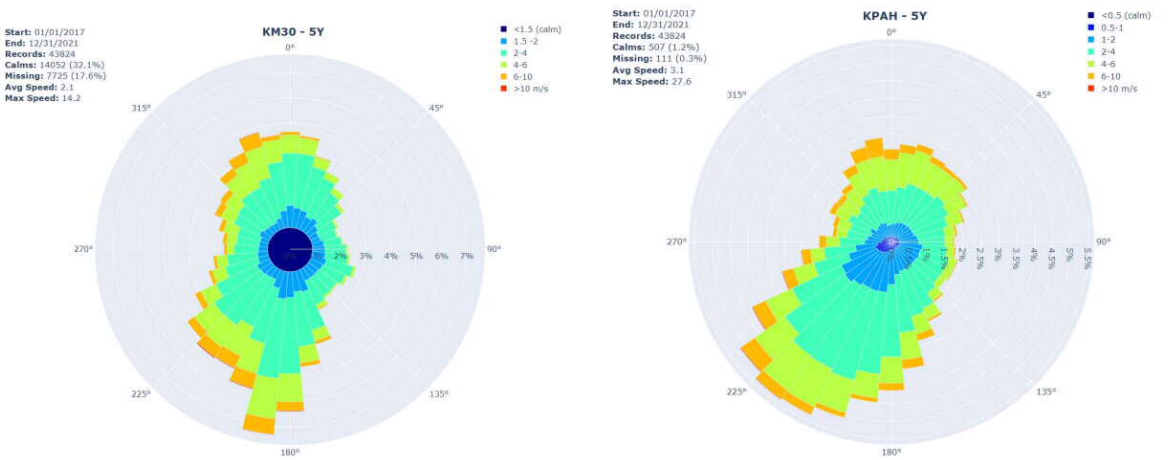

Figure 3-8: Wind rose for a) 2017-2021 at Metropolis Municipal Airport (KM30), and b) 2017-2021 at Paducah Airport (KPAH)

3.2 MTW Uranium Operations

This section details the chemical processing involved in producing UF_6 at MTW.

3.2.1 Description of MTW Operations

The processing of uranium at MTW consists of five key steps[17]:

Ore Sampling and Preparation

Uranium ore in the form of triuranium octoxide (U_3O_8) arrives at MTW in 55-gallon drums which are stored onsite. The drums are sampled to determine the chemical composition of the ore and to identify any potential impurities. The drums are then weighed and relocated to storage until they are ready for use. Uranium ore that contains high levels of sodium or potassium is leached with sulfuric acid (H_2SO_4), and the resulting process-ready uranium is filtered from the rinse solution and transferred to the ore preparation system. The contaminated rinse solution is sent to the uranium settling ponds. Uranium feed that is deemed to have an acceptable level of purity is then calcined, crushed, and classified to create solid particles. The particles are processed in fluidized bed reactors in the Feed Materials Building (FMB). The exhaust stream from this process is filtered in dust collectors in the FMB before being released to the atmosphere.

[17] Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.

Reduction

The solid particles obtained in the previous step are then converted from U_3O_8 to uranium oxide (UO_2) in the FMB by applying hydrogen (H_2) gas in a fluidized bed reactor at a temperature of 1,050 °F. Liquid hydrogen used for H_2 gas is contained in a system maintained by a vendor. The system is monitored for leaks with hydrogen gas analyzers.

Hydrofluorination

Solid UO_2 is then converted to solid uranium tetrafluoride (UF_4) by mixing the UO_2 with gaseous hydrogen fluoride (HF). Gas produced during this reaction is filtered and scrubbed with water and a potassium hydroxide (KOH) solution before being released to the atmosphere. Resulting UF_4 solids are then filtered from the off-gas and transferred to the fluorination reactors.

UF_4 Fluorination

UF_4 is converted to the final chemical product uranium hexafluoride (UF_6) using fluoride (F_2) gas, which is produced in a building adjacent to the FMB. The chemical reaction between the UF_4 and F_2 takes place in a fluidized bed containing calcium fluoride (CaF_2). UF_6 gas is captured after passing through two filters and three cold traps, where it is condensed and transferred to the distillation area. Any gases that exit the cold traps are scrubbed with KOH solution and the resulting potassium fluoride (KF) mud is removed from the scrubber solution, washed, and sent to the uranium recovery system. Filtered and scrubbed off-gases are released to the atmosphere during this step.

UF_6 Distillation and Packaging

UF_6 is processed through low- and high-boiling distillation columns that remove impurities to create a product that meets ATSM C787 (Standard Specification for Uranium Hexafluoride for Enrichment) purity requirements. Gaseous effluents released during this process are fed back to fluorination and treated with the fluorination off-gas. The purified UF_6 vapor is then condensed and packaged in cylinders and moved to storage areas.

A flow schematic of the key steps summarized above is presented in **Figure 3-9**.[18]

[18] Ibid.

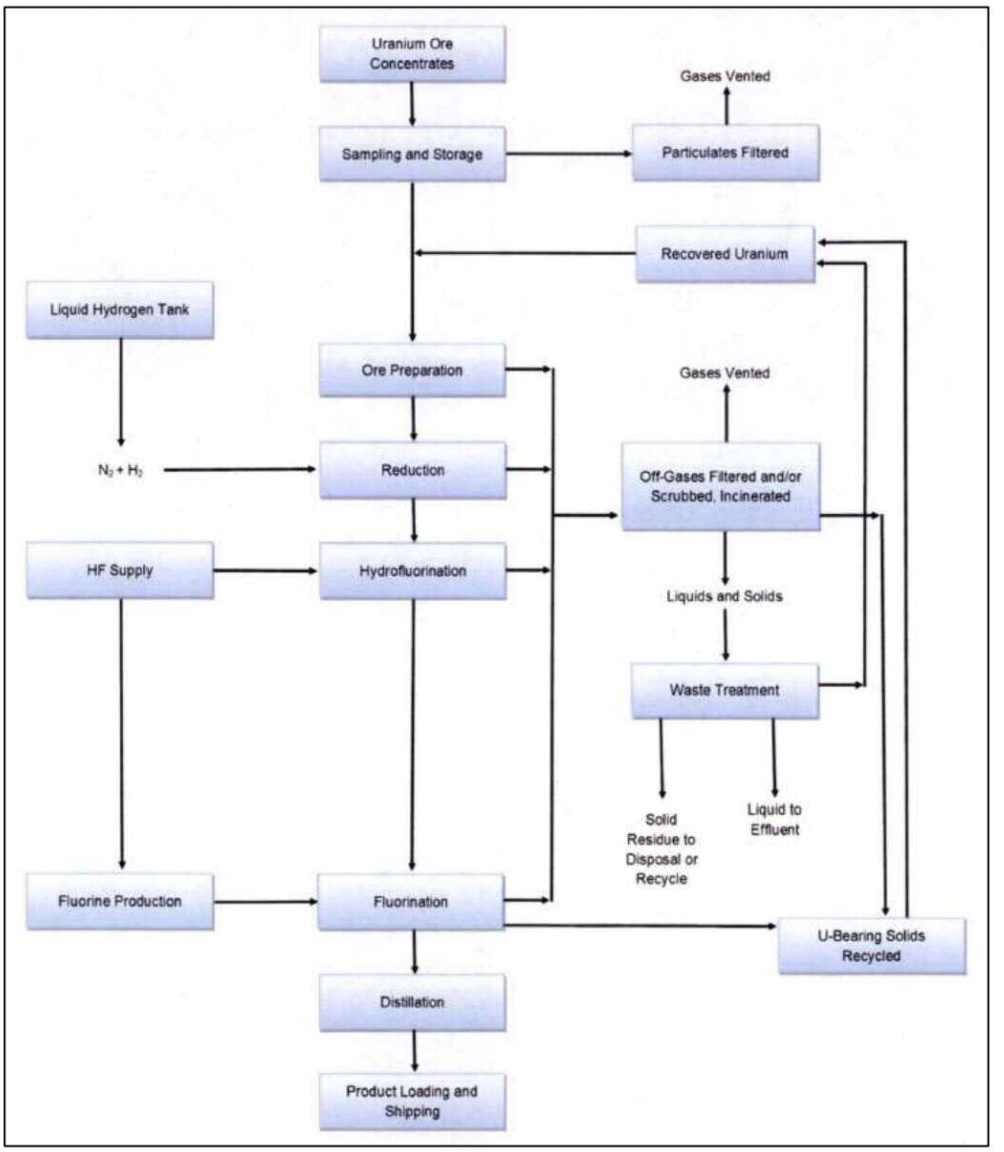

Figure 3-9: Flow schematic of UF_6 production process at MTW

3.2.2 MTW Historical and Current Annual Production

MTW has increased its permitted possession limit of U_3O_8 and annual production capacity of UF_6 through several license renewal applications since its inception. **Figure 3-10** shows the change in permitted annual production capacity of UF_6.[19]

[19] Ibid. The production capacity for 1959 is not included here because the license from 1959 could not be located.

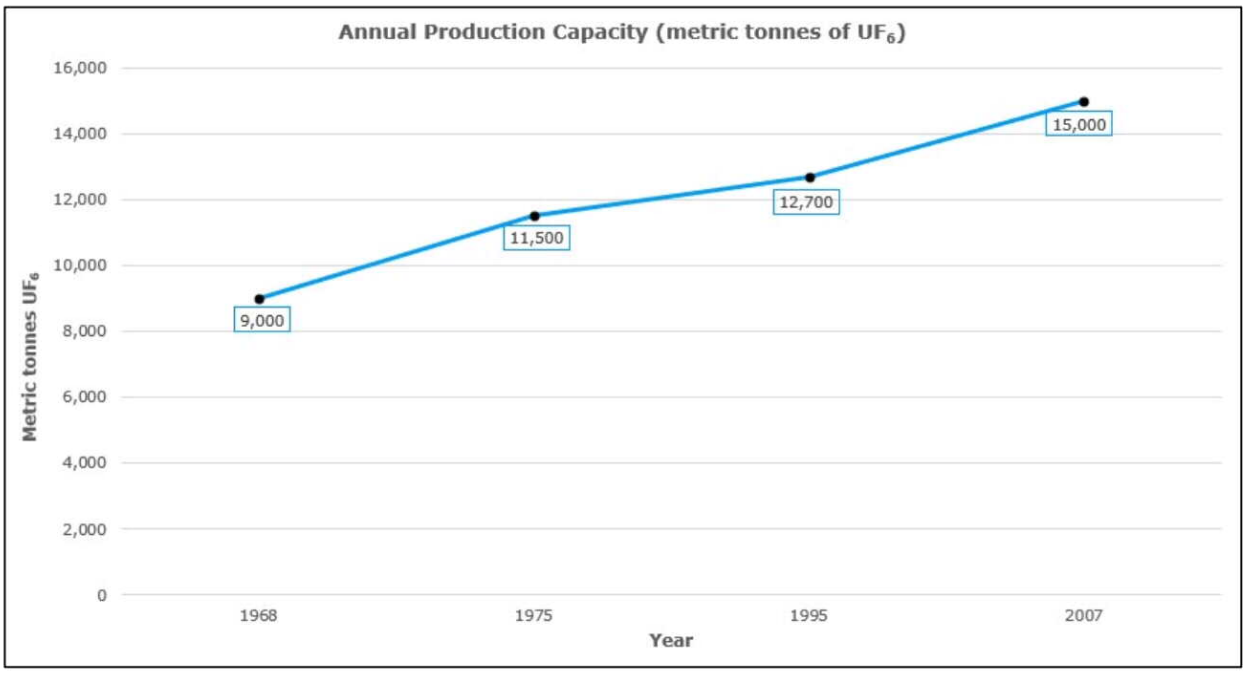

Figure 3-10: Historical annual production capacity

3.3 Emissions from MTW

MTW releases both radiological and non-radiological emissions during UF_6 production. Radiological emissions from individual stacks are summarized in uranium accountability reports issued by MTW. Uranium accountability reports in turn are used to generate annual emissions data that are presented in environmental reports submitted to the NRC in support of license renewal applications.

3.3.1 Chemical Species Typically Released from MTW

The principal radiological constituents released from MTW include isotopes of uranium and its decay products radium-226 and thorium-230. Non-radiological emissions include volatile organic material (VOM), sulfur dioxide (SO_2), particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and hazardous air pollutants (HAP).[20] This report focuses on emissions of radiological constituents and does not evaluate non-radiological constituents. Monitoring of onsite and offsite impacts is summarized in Section 3.5.

3.3.2 Methods for Estimating Emissions from MTW

MTW estimates emissions from the Facility using a number of methods, as summarized below.

Uranium Accountability Reports

MTW estimates emissions from the Facility by collecting gaseous effluent samples from release points (e.g., stacks, vents, exhaust fans) using particulate filters. Samples are collected at

[20] Ibid.

isokinetic conditions at a frequency of once or twice every 24 hours, and uranium loss from each release point is summarized in daily, monthly, and annual accountability reports.[21]

Environmental Reports in Support of License Renewal Applications

Annual emissions for each release point are presented in environmental reports and impact assessments submitted in support of license renewal applications, including applications submitted in 1975, 1984, 1995, 2005, and 2017. Emissions data in these reports rely on the accountability reports discussed in the previous paragraph. Depending on the year the report was issued, emissions data are presented in either mass (e.g., grams) or radioactivity (e.g., Curies, or Ci). To estimate radioactivity for a given mass of emissions, MTW applies a specific activity of 6.77×10^{-7} Curies per gram (Ci/g) of uranium loss observed in accountability reports, consistent with guidance from the NRC.[22]

Facility Effluent Reports

While accountability reports contain emissions in terms of grams lost from each release point, six-month effluent reports submitted to the NRC contain facility-wide emissions of radionuclides expressed in Curies. These reports account for emissions of all known isotopes of natural uranium (Uranium), which includes uranium-234 (U-234), uranium-235 (U-235), and uranium-238 (U-238).[23] These reports also include radioactivity associated with radium-226 (Ra-226) and thorium-230 (Th-230), the principal decay products of uranium. MTW estimates the amount of uranium radioactivity released by applying a specific activity of 6.77×10^{-7} Ci per gram (Ci/g) of uranium.[24] MTW measures the amount of radioactivity from decay products in uranium oxide ore received at the Facility prior to use in the UF_6 conversion process by taking a representative sample of each drum. The weight of each drum, and its associated radium and thorium activity in picocuries per gram of uranium (pCi/g U), are recorded in documents entitled "Mill Code Dump Reports".[25] This radioactivity is averaged over six-month periods, separated into the first and second half of each year. The average radioactivity of Ra-226 and Th-230 is then multiplied by the grams of uranium lost in the same period to estimate total Ci released to the atmosphere.[26]

3.3.3 Emissions Inventory for MTW

Facility-wide uranium emissions are summarized in **Figure 3-11**.[27]

[21] Ibid.
[22] United States Nuclear Regulatory Commission. Footnotes for radionuclide tables in 10 CFR Part 20 Appendix B. Available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/footnotes.html. Accessed November 13, 2023.
[23] International Atomic Energy Agency. Depleted Uranium. Available at: https://www.iaea.org/topics/spent-fuel-management/depleted-uranium. Accessed November 2, 2023.
[24] United States Nuclear Regulatory Commission. Footnotes for radionuclide tables in 10 CFR Part 20 Appendix B. Available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/footnotes.html. Accessed November 13, 2023.
[25] For example, see: Honeywell. 2012. Mill Code Dump Report. HONSteward-0001289.
[26] For example calculation, see: Honeywell. 2009. NRC Effluent Report Calculations. HONSteward-0229606 - HONSteward-0229893.
[27] Three different sources were utilized to summarize facility-wide emissions from 1969-2018. Emissions data for 1969 and 1970 were contained in monthly operating reports for each year (see HONSteward-0473987 and HONSteward-0422073). Emissions data from 1971-1975 were contained in uranium accountability reports for each year (see HONSteward-0502507 – HONSteward-0502622). Emissions data from 1976-2018 were contained in facility-wide effluent reports submitted to the NRC (see HONSteward-0225807 – HONSteward-0226060).

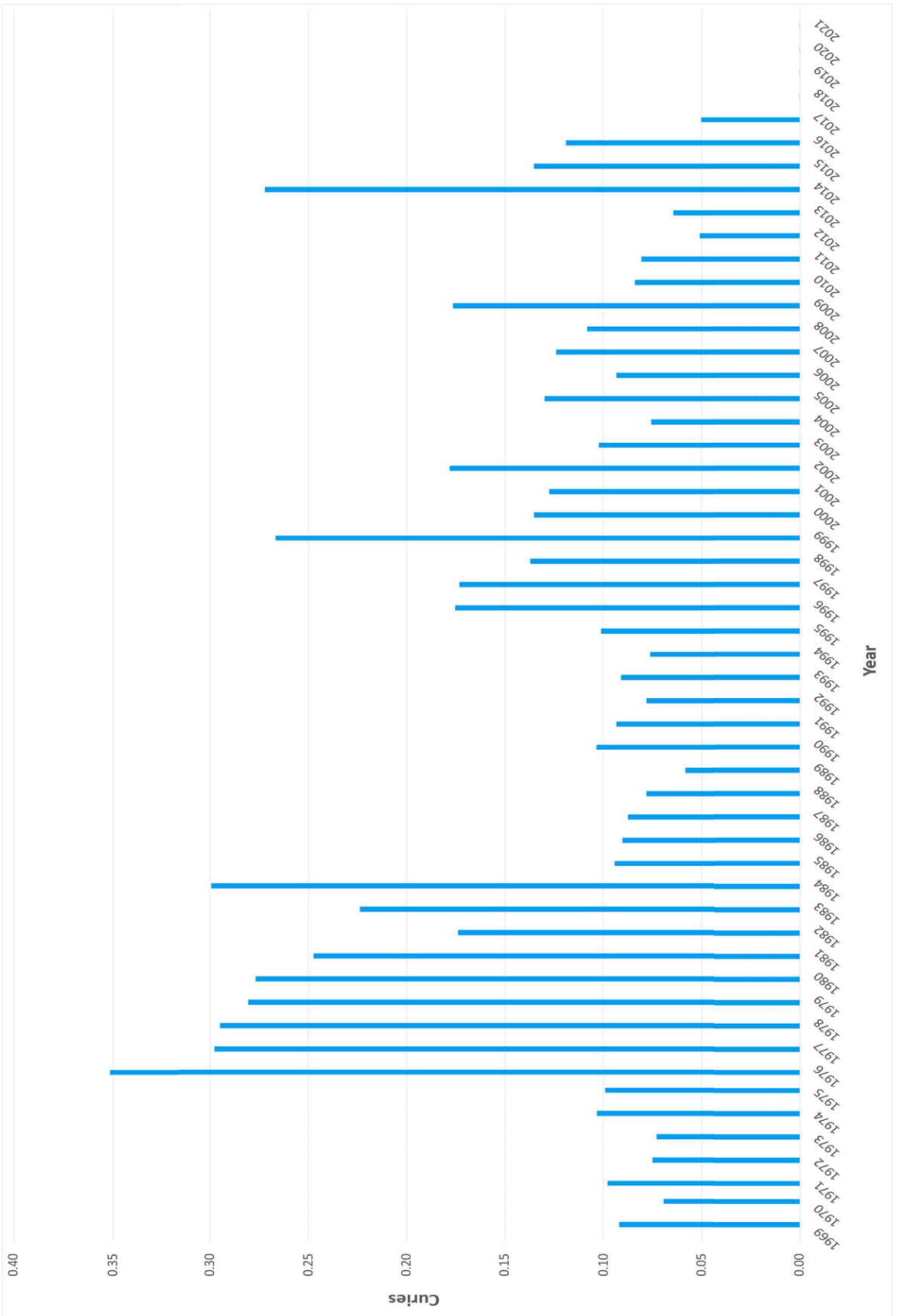

Figure 3-11: Facility-wide uranium emissions

3.4 Ambient Air at and Near the Site

3.4.1 Background Concentrations

Quantifying the background concentration of radioactive material in the air is an inherently complex task, influenced by factors including location, time, altitude, geography, and local geology, as well as the impact of human activities. There are numerous natural sources of background radiation such as cosmic rays, terrestrial emissions like radon gas, and trace amounts of naturally occurring radioactive elements like uranium, which are found not only in the environment but also within our bodies. The air itself is a blend of various radionuclides, each characterized by unique decay processes and energy emissions. The primary challenge in this context lies in differentiating and precisely quantifying these radionuclides. We have found no definitive source on the regional background concentration of radioactive materials, or indeed a useful understanding of what constitutes background.

Background concentrations of radioactive materials is heavily dependent on localized factors, such as the specific weather patterns and the unique composition of soils in different regions.[28,29,30] For instance, the radioactive species concentrations found in urban settings like Chicago and New York City, as referenced in Dr. Auberle's report, may not be relevant or useful for comparison with an area like the City of Metropolis. Each location is governed by its own environmental conditions, which in turn affect the presence and levels of radioactive elements. This underlines the challenge of using standard background concentrations as a yardstick for assessing the radioactive status of a particular location.

3.5 Ambient Air Monitoring

3.5.1 Description of Facility Monitoring Program

MTW's ambient air monitoring program consists of eight continuous monitoring stations, as shown in **Figure 3-12**. Continuous air monitoring began in 1977 and replaced air gum paper fallout sampling. Four air monitors are along the fenceline (Stations No. 9, 10, 12, and 13), two monitors are located in the predominant downwind direction from MTW (Stations No. 8 and 11), one monitor is by the nearest residence (NR-7), and one monitor is by the Metropolis Municipal Airport (Station No. 6). NR-7 changed locations in 1987 due to a change in the location of the nearest residence. The monitors measure concentrations of uranium, radium-226, thorium-230, and fluoride. Air monitor filters are collected and replaced weekly and analyzed for uranium and fluoride. Composites of the weekly filters are analyzed quarterly for radium and thorium.

Ambient air monitoring is effective in capturing both the ambient air concentrations that result from routine emissions from MTW and ambient air concentrations that result from upset conditions should they occur, such as unplanned releases of uranium due to power failures, equipment malfunctions, breached containers, or other episodes.

[28] EPA. 2023. What is background radiation? Is background radiation a risk to me and my family? Available at: https://www.epa.gov/radiation/what-background-radiation-background-radiation-risk-me-and-my-family. Accessed November 14, 2023.
[29] EPA. 2023. What is a normal background exposure rate? Available at: https://www.epa.gov/radnet/what-normal-background-exposure-rate. Accessed November 13, 2023.
[30] EPA. 2023. How does precipitation affect radiation levels in the environment? Available at: https://www.epa.gov/radnet/how-does-precipitation-affect-radiation-levels-environment. Accessed November 14, 2023.

Figure 3-12: Location of MTW ambient air monitoring stations

3.5.2 Description of IEMA Monitoring Program

The Illinois Emergency Management Agency and Office of Homeland Security (IEMA) has an air monitoring program that consists of seven monitoring stations, as shown in **Figure 3-13**. The IEMA air monitoring program has been in operation since at least 1996 and has continued to present day. There are over 3,000 air monitoring IEMA data points available from historical IEMA records and reports. Starting in 2016, the Hospital Roof monitor shown in Figure 3-13 was decommissioned, and in November of 2013, the Water Treatment Plant monitor was moved to Dorothy Miller Park. The Airport Road monitor began collecting data in 2017. The air particulate filters at these monitoring stations are analyzed weekly for gross alpha and beta activity. Since IEMA monitors gross alpha and beta, the IEMA results are not directly comparable to concentrations measured at monitoring stations operated by MTW. In particular, even if uranium,

thorium, and radium concentrations detected at MTW monitors are summed, the sum cannot be compared to total alpha measured at the IEMA monitors because total alpha would account for other sources of radiation in the environment, such as radon. Nevertheless, the IEMA monitoring results are useful in detecting trends in total alpha activity and generally corroborate the MTW monitoring and air modeling trends (modeling is discussed in Section 4).

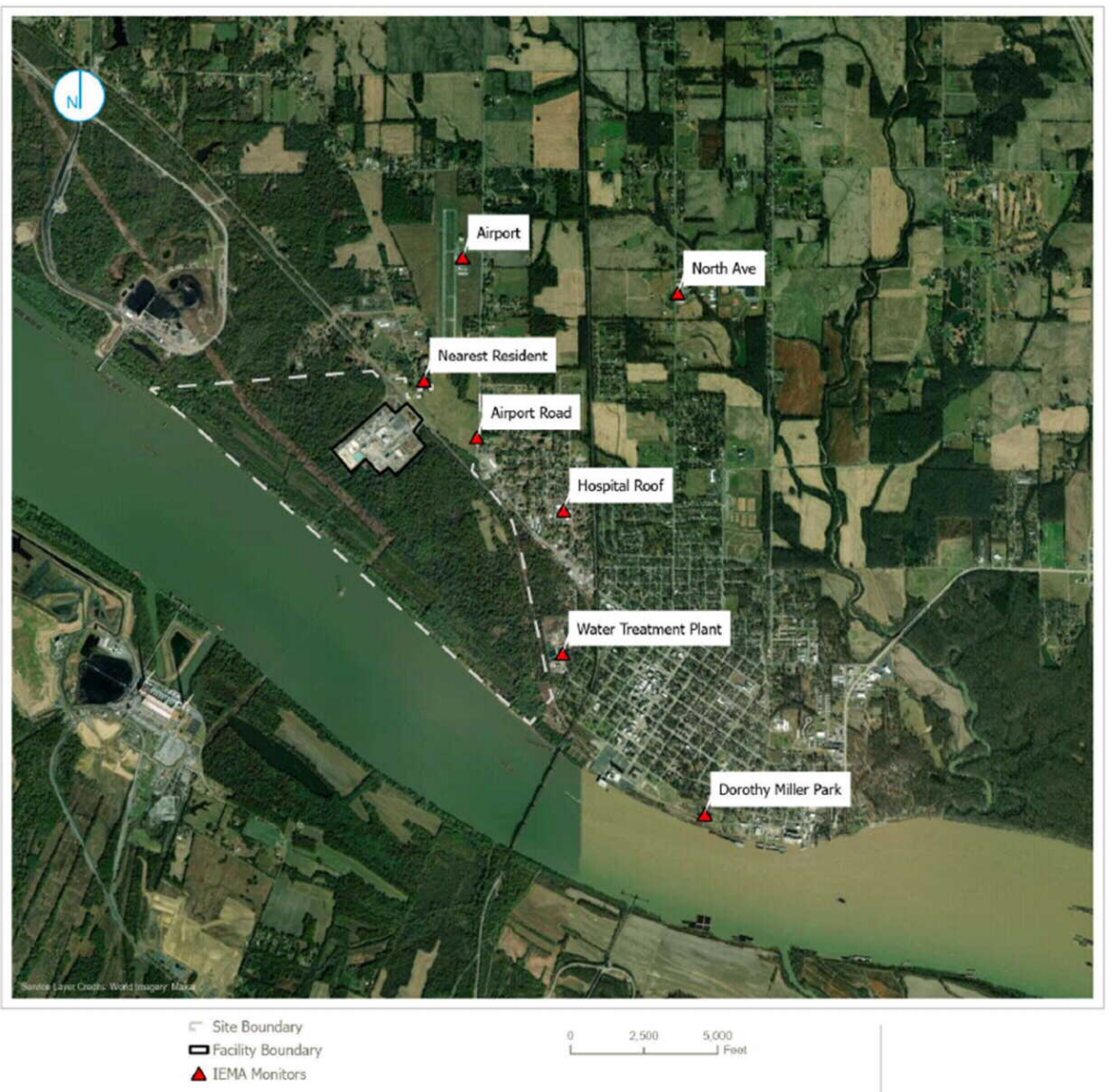

Figure 3-13: Location of IEMA monitoring stations

4. AIR DISPERSION MODELING OF URANIUM EMISSIONS FROM MTW

This section describes the air dispersion modeling conducted at my direction to estimate ambient air concentrations of uranium-based radiation from MTW at various locations in the Metropolis community. It includes details on the methods used to estimate ambient air concentrations as well as the results.

4.1 Current Methods for Modeling Air Dispersion from the Site

Air dispersion models are widely used to help determine the impact of air emissions to the environment. Modeling is a reasonable way of estimating ambient air concentrations where no monitoring data exist and can be used to understand patterns of air concentrations at sites where discrete monitoring exists.

Air quality models can be broadly categorized as Gaussian plume or steady state models (AERMOD, ADMS, ISCST3), Lagrangian puff models (CALPUFF, SCIPUFF) and Eulerian grid models (CAMx, CMAQ). The model category is chosen based on the specific application. Steady state models are most frequently used for regulatory purposes and are considered appropriate for modeling air concentrations up to 50 kilometers (km) from the source.[31]

4.2 AERMOD Dispersion Model

AERMOD is a Gaussian, steady state model, created by the United States Environmental Protection Agency (EPA) to support regulatory development and represents the agency's preferred air dispersion modeling tool.[32] In AERMOD, emissions from the source are dispersed in the direction of the prevailing wind. Over the time period needed for the plume to reach each "receptor" (i.e., a discrete location at which the concentration and deposition are calculated by the model), meteorological conditions are assumed to be constant. The dispersion rate, expressed as a normal Gaussian distribution in both horizontal and vertical directions, increases with distance. AERMOD is limited in its ability to simulate calm conditions or light and variable winds. Additionally, AERMOD cannot accurately reproduce complex wind patterns caused by terrain channeling or the recirculation of pollutants, which are unlikely to impact the accuracy of the model here due to the relatively flat terrain in Metropolis.

AERMOD can simulate a variety of source types including point, volume, area, open pit, and both buoyant and non–buoyant line sources. It can be used for multiple sources in a single model run. The driving meteorology is prepared by the preprocessing tool AERMET. The meteorological data, input to AERMET, are extracted from the National Weather Service (NWS) or Federal Aviation Administration (FAA) hourly surface observations, or from onsite meteorological measurements when available, as well as from twice-daily upper air soundings. The AERSURFACE preprocessor is used to derive the surface characteristics based on the land use at the meteorological station. The terrain elevation of sources and receptors are processed using the preprocessor AERMAP.

[31] 40 CFR Part 51, Appendix W. 2017. Guideline on Air Quality Models. Vol. 82, No. 10. January 17. https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. Accessed November 10, 2023.
[32] Ibid.

4.3 Modeling Setup

As part of this report, a dispersion modeling demonstration was performed at my direction to assess ambient air activity concentrations and deposition rates in the area surrounding MTW. The setup of the modeling demonstration is discussed in this section.

4.3.1 Dispersion Model Selection and Application

I selected AERMOD as the dispersion model to be used in the demonstration. As noted, AERMOD is EPA's preferred dispersion model for assessing near-field dispersion of emissions at distances of up to 50 km. During the course of this modeling, EPA released a new regulatory version of AERMOD and its pre-processor AERMET (Version 23132) which was used in this analysis.

The model was conducted using the Method 1 deposition algorithm consistent with Dr. Auberle's analysis. Method 1 is an algorithm approved for use in regulatory modeling that estimates the rate of particle outfall from the atmosphere. Method 1 requires prescribing a set of particle diameters, mass fractions of particles belonging to each diameter range, and the density of particles in each subgroup. The model was run with the same choices of particle diameter, mass fraction, and density used by Dr. Auberle.

4.3.2 Meteorological Data

A five-year meteorological database was constructed at my direction using the available surface and upper air data for the dispersion modeling analysis. Meteorological data were processed through AERMET, Version 23132.

Meteorological data from the Paducah Airport were used in constructing the air dispersion model. As noted in Section 3.1.5, potential sources of surface meteorological observations include the Metropolis Airport (KM30) and the Paducah Airport (KPAH). Although the Metropolis Airport is the closest meteorological station to the MTW site, there are several attributes of the Paducah Airport data as compared to the Metropolis Airport data that make the Paducah Airport a better data source for purposes of air dispersion modeling.

First, as noted in Section 3.1.5, for the five-year period from 2017-2021, there were 9,593 hours at the Metropolis Airport missing at least one meteorological parameter required by AERMOD. This constitutes over 20 percent of hours in the period. In contrast, for the 2017-2021 period at Paducah Airport, there were only 131 hours where at least one surface meteorological parameter required by AERMOD was missing. AERMOD disregards hours where required parameters are missing and does not calculate a concentration or deposition value for that hour. Accordingly, using a meteorological record with as few missing hours as possible provides more complete model results.

Second, 1-minute resolution wind speed data is not available for the Metropolis Airport station, whereas such data is available for the Paducah Airport station. The main source of National Weather Service surface meteorological data used in AERMOD demonstrations is the Integrated Surface Database (ISD).[33] The wind speeds recorded in the ISD are a 2-minute average wind speed obtained near the end of each hour. To collect data, the Paducah Airport station uses the Automated Surface Observing System (ASOS), for which wind data is also archived at 1-minute

[33] National Centers for Environmental Information. Global Hourly - Integrated Surface Database (ISD). Available at: https://www.ncei.noaa.gov/products/land-based-station/integrated-surface-database. Accessed November 10, 2023.

resolution, rather than the hourly resolution available in the ISD. The Metropolis Airport station is not an ASOS site but instead uses the older Automated Weather Observing System (AWOS). The 1-minute resolution data is not available for AWOS stations.

Third, and related, the ISD database records wind speed values of less than 1.5 m/s as calm. The 1-minute ASOS database, in contrast, includes raw wind values of less than 1.5 m/s. This distinction is important because the Gaussian dispersion parameterization used in AERMOD is not able to handle calm winds, and consequently AERMOD is programmed to skip hours recorded as calm and no concentration or deposition calculations are performed. Therefore, if ASOS 1-minute data is available, modeling best practice is to process the ASOS 1-minute data to backfill as many calm hours as possible.[34] Only wind speeds of less than 0.5 m/s are then treated as calm observations by the AERMOD system.

These variables have a significant impact here. As noted, the Metropolis Airport site is not an ASOS station, so no 1-minute resolution wind speed is available. Reviewing the ISD data for the site for the 2017-2021 period, there are a total of 13,113 hours recorded out of a total possible 43,824 hours where the required parameters are present, but winds are recorded as calm. This is in addition to the 9,593 hours that are missing parameters as described above. When considering the missing data and calm hours in total, AERMOD would only be able to produce valid concentrations and deposition results for less than half of the hours in the 2017-2021 period when using the Metropolis Airport data.

In contrast, the Paducah Airport site is an ASOS station, so 1-minute resolution wind data are available for processing. In the five-year period (2017-2021) considered, there are only 507 calm hours remaining after processing of the 1-minute data. This equates to about 1.2 percent of hours in the period. Additionally, there are 131 hours in the five years at Paducah Airport (about 0.3 percent) with a missing required meteorological parameter. After removing the calm and missing data, there are about 98.5 percent of hours available in the Paducah Airport surface meteorological record that are acceptable for use in AERMOD and that will produce hour-specific concentration and deposition values.

Given the robust data completeness and the availability of the 1-minute resolution data to eliminate most ISD calm observations, the Paducah Airport station was used for surface meteorological data. The 1-minute resolution data was processed through the most recent version of AERMINUTE (v15272).

AERMET requires upper air sounding data in addition to surface data. Upper-air data were obtained from weather balloons launched at Nashville, Tennessee (KBNA), the closest upper-air station to Metropolis. Data were downloaded from the NOAA/GSL radiosonde database[35] and included in the analysis.

4.3.3 Emissions and Averaging Periods

Air dispersion modeling demonstration for the entire MTW operating period for which source-by-source emissions were available was performed using five-years (2017-2021) of meteorological

[34] EPA. 2013. "Use of ASOS meteorological data in AERMOD dispersion modeling." Available at: https://www.epa.gov/sites/default/files/2020-10/documents/20130308_met_data_clarification.pdf. Accessed November 17, 2023.
[35] NOAA. 2022. NOAA/GSL Radiosonde Database. Available at: https://ruc.noaa.gov/raobs/. Accessed November 10, 2023.

data consistent with guidance on using offsite meteorological stations.[36] AERMOD was run with the PERIOD averaging time option. This option produces the average concentrations over the entire five-year period at each receptor, as well as the sum of the deposition calculated in each hour over the five-year period. Hence, for each receptor the demonstration produces a single concentration result and a single deposition result for the entirety of the model run.

The AERMOD modeling was performed assuming pollutants are inert (i.e., there was no chemical creation or destruction of the modeled pollutant). As a result, the effects of multiple emission units at a receptor are additive; that is, the concentration or deposition due to all emission sources is simply the sum of the concentration or deposition from each individual emissions source. As the effects of the multiple emissions sources may be combined through simple addition, and there is one result for concentration and deposition at each receptor associated with the entire model period run, the model may be run with unit emissions and then concentration and deposition can be calculated in a post-processing step. During the post-processing, the unitized concentration and deposition factors at each receptor for each emissions source are multiplied by the emission rates of each source, then summed across all emissions sources to calculate total concentration and deposition. The use of a unit emission rate and a post-processing scaling analysis is often used within the industry to investigate impacts from sources with variable emissions, since it permits AERMOD to be run only once.[37] The unit emissions approach is also commonly used in some states requiring dispersion modeling of air toxics for permitting purposes, as each toxic species will have a unique conversion factor from emission rate to health risk while the relative dispersion pattern from each emission unit is fixed.[38]

Accordingly, for the AERMOD input, an emission rate of 1 Curie per second (Ci/s) was prescribed for each unit. The outputs of the model are then in terms of microcuries per cubic meters ($\mu Ci/m^3$) for period-average activity concentrations, and Curies per square meter (Ci/m^2) for period-total deposition. These results can then be scaled by the emission rates unique to each year to obtain annual contributions to activity concentration and deposition for each unit. The results presented herein are in terms of microcuries per mL for concentration and milligrams per square meter for deposition, so appropriate conversion factors were additionally applied. The deposition values can be summed across MTW's span of operation to obtain a cumulative deposition total. Note that since the AERMOD demonstration was run for a five-year period and outputs total period deposition, a weighting factor of 1/5 was also applied to obtain deposition values for any one particular year.

4.3.4 Stack Parameters

All emission units at MTW are stacks or vents and were modeled as point sources (either vertically or horizontally oriented).

Required AERMOD source inputs for point sources include source locations (in UTM coordinates), stack heights, exhaust temperatures, exhaust velocities, and stack diameters. Historical

[36] 40 CFR Part 51, Appendix W. 2017. Guideline on Air Quality Models. Vol. 82, No. 10. January 17. https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. Accessed November 10, 2023.
[37] Texas Commission on Environmental Quality. 2021. Howard County Monte Carlo Simulations. Available at: https://www.tceq.texas.gov/downloads/air-quality/sip/so2/howard/21010sip_howard_adsip_appendixl_pro.pdf. Accessed November 11, 2023.
[38] Oregon Department of Environmental Quality. 2022. Recommended Procedures for Air Quality Dispersion Modeling. Available at: https://www.oregon.gov/deq/aq/cao/Documents/CAORP-AirQualityModeling.pdf. Accessed November 11, 2023.

documentation was reviewed and values were obtained from these reports if available.[39, 40, 41,42, 43,44,45] MTW personnel subsequently confirmed these values from available reports and provided measured values for parameters that I could not obtain from available documentation.

In the process of reviewing and confirming source parameters, MTW staff indicated that several sources experienced changes to their outflow parameters over the course of MTW's operation. Key changes are summarized below:

- Source 1-7 (UF_4 vacuum cleaner) was replaced in 2013; the new source had a lower flow rate;
- Source 1-10 ("B" UF_4 dust collector) had a scrubber installed in the early 1990s, which lowered the flow rate;
- Source 1-46 ("A" UF_4 dust collector) had a scrubber installed in the early 1990s, which lowered the flow rate;
- Source 1-49 (Distillation Multi-Floor Exhaust) had a stack height increase and flow rate decrease at the end of 2013.

In order to account for the changes in source parameters, two sources were set up in AERMOD for each of these units: one reflecting source parameters before the change and one reflecting source parameters after the change. For example, in the model, source 1-7 was represented by AERMOD emission unit "1_7_A" and "1_7_B", which differ in their exhaust velocity. In the post-modeling scaling, emissions from source 1-7 were assigned to AERMOD emission unit "1_7_A" (with zero emissions assigned to unit "1_7_B") for periods before the equipment replacement. Emissions were assigned to "1_7_B" (and set to zero for "1_7_A") after the equipment replacement. Based on the dates of changes to sources at the Facility, the following was employed in the modeling and post-processing:

- Source 1_7_A (with its higher flow rate) was used for UF_4 vacuum cleaner emissions for years up to and including 2012. Source 1_7_B (with its lower flow rate) was used for UF_4 emissions for year 2013 and onward.
- Source 1_10_A (with its higher flow rate) was used for "B" UF_4 dust collector emissions for years up to and including 1991. Source 1_10_B (with its lower flow rate) was used for "B" UF_4 emissions for year 1992 and onward.

[39] Allied Chemical Company. 1975. Environmental Information Allied Chemical Corporation Metropolis, Illinois Facility License No. Sub-256 Docket No. 40-392. June 17. HONSteward-0497728.
[40] Allied Chemical Company. 1984. Environmental Impact Appraisal for Renewal of Source Material License No. SUB-256 Docket No. 40-3392. May. NRCADAMS071162.
[41] Allied Signal, Inc. 1995. Environmental Assessment for Renewal of Source Material License SUB-256 Docket 40-3392. April 10. NRCADAMS071049.
[42] Enercon Services, Inc. 2005. Environmental Report Renewal of Source Material License SUB-256 Docket No. 40-3392 for Honeywell Specialty Materials. May 25. HONSteward-0892794.
[43] Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.
[44] Metropolis Works 1978 Stack Emissions. HONSteward-0231476 - HONSteward-0231526.
[45] Allied Chemical Company. UF_6 Facility Stack Emissions 1971 Data. May 11. HONSteward-0498420 – HONSteward-0498422

- Source 1_46_A (with its higher flow rate) was used for "A" UF_4 dust collector emissions for years up to and including 1991. Source 1_46_B (with its lower flow rate) was used for "A" UF_4 emissions for year 1992 and onward.
- Source 1_49_A (with its lower stack and higher flow) was used for distillation multi-floor exhaust emissions for years up to and including 2013. Source 1_49_B (with its higher stack and lower flow) was used for distillation multi-floor exhaust emissions for year 2014 and onward.

4.3.5 Building Downwash

Building downwash is a term describing the effect of nearby structures on the flow of emissions from their respective sources. I evaluated building downwash using the EPA-approved Schulman-Scire method. I used the EPA-approved Building Profile Input Program (BPIP) to calculate the projected building widths and heights for use in the dispersion modeling.

Required inputs to the BPIP program include the vertices (corners) of buildings as well as their roof heights. Historical documentation was reviewed at my direction to determine if such information was available from these sources. A 1980 plot plan identified many buildings and their roof heights and was the primary source for much of this information.[46] Using the plot plan and georeferenced satellite photography, the coordinates of the individual buildings were determined. MTW staff provided information for several buildings whose coordinates and heights could not be obtained from historical documentation. MTW staff communicated that building coordinates and heights have remained fixed over time.

4.3.6 Receptors

The locations of the gridded receptors used in this demonstration generally were the same as those used in Dr. Auberle's modeling. An inner grid of receptors spaced 100 meters (m) apart and an outer grid of receptors spaced 500 m apart were included. Dr. Auberle's modeling also included 26 discrete receptors. The first 19 receptors matched the locations of Plaintiff residences. It is unclear as to what the remaining seven discrete receptors represent. Some of the remaining seven receptors are close to locations of IEMA monitors, but others are not. For comparison to Dr. Auberle's modeling, I retained all discrete receptors in my modeling demonstration. Several additional residential addresses representing class plaintiff locations that were not represented in Dr. Auberle's modeling were also added.

In addition, I modeled discrete receptors placed at the monitoring locations surrounding MTW operated both by Honeywell and by IEMA.

Finally, 12 additional receptors representing disparate residential locations within the proposed Class Area were also modeled to illustrate the uneven distribution of impacts in the area. Results at these receptors are discussed in Section 8.

[46] Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.

Terrain data for the receptors were obtained from the National Elevation Dataset[47] with 1/3 arcsecond resolution. These data were processed in the current regulatory version of AERMAP (v18081) to obtain elevations and hill scale heights at each receptor.

4.3.7 Land Use and Precipitation Analysis

Some meteorological parameters required by AERMOD are calculated from land use and surface characteristics rather than obtained directly from surface or weather-balloon observations.

The most recent version of AERSURFACE (v20060) was used to determine the surface characteristics for use in conjunction with the meteorological data. Land cover data from the 2016 USGS National Land Cover Database[48], supplemented with percent impervious and percent tree canopy data from 2016, were used in the analysis.

A seasonal distribution must be prescribed to AERMET. Review of Paducah's climatology indicates a strongly seasonal climate with hot summers and cold winters. The default seasonal assignment for AERSURFACE is appropriate for the area and was employed as follows:

- Spring: March, April, May
- Summer: June, July, August
- Autumn: September, October, November
- Winter: December, January, February

AERSURFACE has an arid option for processing land use data in dry climates. This option is not appropriate for the Paducah region and was not used.

AERSURFACE also contains an option for processing months as having continuous ground snow cover. A review of Paducah's climatology indicated that, while snow does occur in winter, snowfall totals are small. No month averages greater than 3 inches snowfall for the entire month. Additionally, all months of the year have a daily-mean temperature of greater than freezing, so when minor snowfall events do occur, rapid melting would be expected to follow. Accordingly, continuous snow cover is not expected for any month of the year and the option was not employed.

AERSURFACE requires that a number of sectors be specified for the calculation of one of the land-use parameters, the surface roughness. Twelve separate sectors, each 30 degrees in width, were utilized in the determination of the surface roughness. This is the maximum number of sectors allowed by AERSURFACE. It is also required to specify whether the location of the meteorological station used is at an airport and the Paducah site was so identified.

A precipitation analysis was performed to determine the monthly moisture condition at the surface meteorological data station (i.e., average, wet, dry). Following the recommendation in the AERSURFACE User's Guide, which states that "a recommended approach is to determine

[47] USGS. 2018. The National Elevation Dataset. Available at: https://www.usgs.gov/publications/national-elevation-dataset. Accessed November 11, 2023
[48] Earth Resources Observation and Science Center. 2018. National Land Cover Database. Available at: https://www.usgs.gov/centers/eros/science/national-land-cover-database. Accessed November 11, 2023

moisture conditions either seasonally or monthly,"[49] a monthly resolution was employed. The monthly precipitation data for 2017-2021 was compared with the most recent National Centers for Environmental Information (NCEI) 30-year climatological period (1991-2020) to determine the monthly surface moisture condition and corresponding surface characteristics for incorporation into Stage 3 of AERMET. Consistent with guidance from EPA and industry practice, for each month, "wet" conditions were selected when precipitation is in the upper 30th percentile for climatological conditions for that month, "dry" conditions when precipitation was in the lower 30th percentile, and "average" conditions when precipitation was in the middle 40th percentile.[50]

4.4 Results of Modeling Emissions from MTW

Modeled average period activity concentration and total (cumulative) period deposition are plotted in **Figures 4-1 and 4-2**. Both figures show results as a fraction of the results predicted by the model at monitor location NR-7 (i.e., 75% of NR-7, 50% of NR-7, etc.). NR-7 was selected because it is the residential/offsite location that is most exposed from airborne radiological releases from MTW.

As noted in Section 4.3.3, since modeling was conducted for sources with unitized emission rates (i.e., 1 Ci/s), deposition and airborne concentrations were scaled by the appropriate emission rate. Activity concentrations attributable to each emission source in a single year are summed over each source to produce an overall activity concentration value for each year at each location. Finally, these annual-average activity concentration values are averaged over the modeled period of operation (1971-2018) to obtain the period-average activity concentration at each location.

A similar process is used to obtain the overall (cumulative) deposition results. The modeled period total deposition values for a 1 Ci/s emission rate from each source are scaled by the appropriate emission rate for each source and year including an additional weighting of 1/5, as the outputs from the AERMOD model were period total (5-year) deposition values, not an annual average. Deposition attributable to each emission source in a single year is summed to produce an overall deposition value for each year. These annual-total deposition values are summed over the modeled period of operation (1971-2018) to obtain a period-total cumulative deposition rate, and is based on the weighted average of uranium isotopes.[51]

[49] EPA. 2020. User's Guide for AERSURFACE Tool. EPA-454/B-20-008. February. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aersurface/aersurface_ug_v20060.pdf. Accessed November 14, 2023.
[50] Ibid.
[51] United States Nuclear Regulatory Commission. Footnotes for radionuclide tables in 10 CFR Part 20 Appendix B. Available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/footnotes.html. Accessed November 13, 2023.

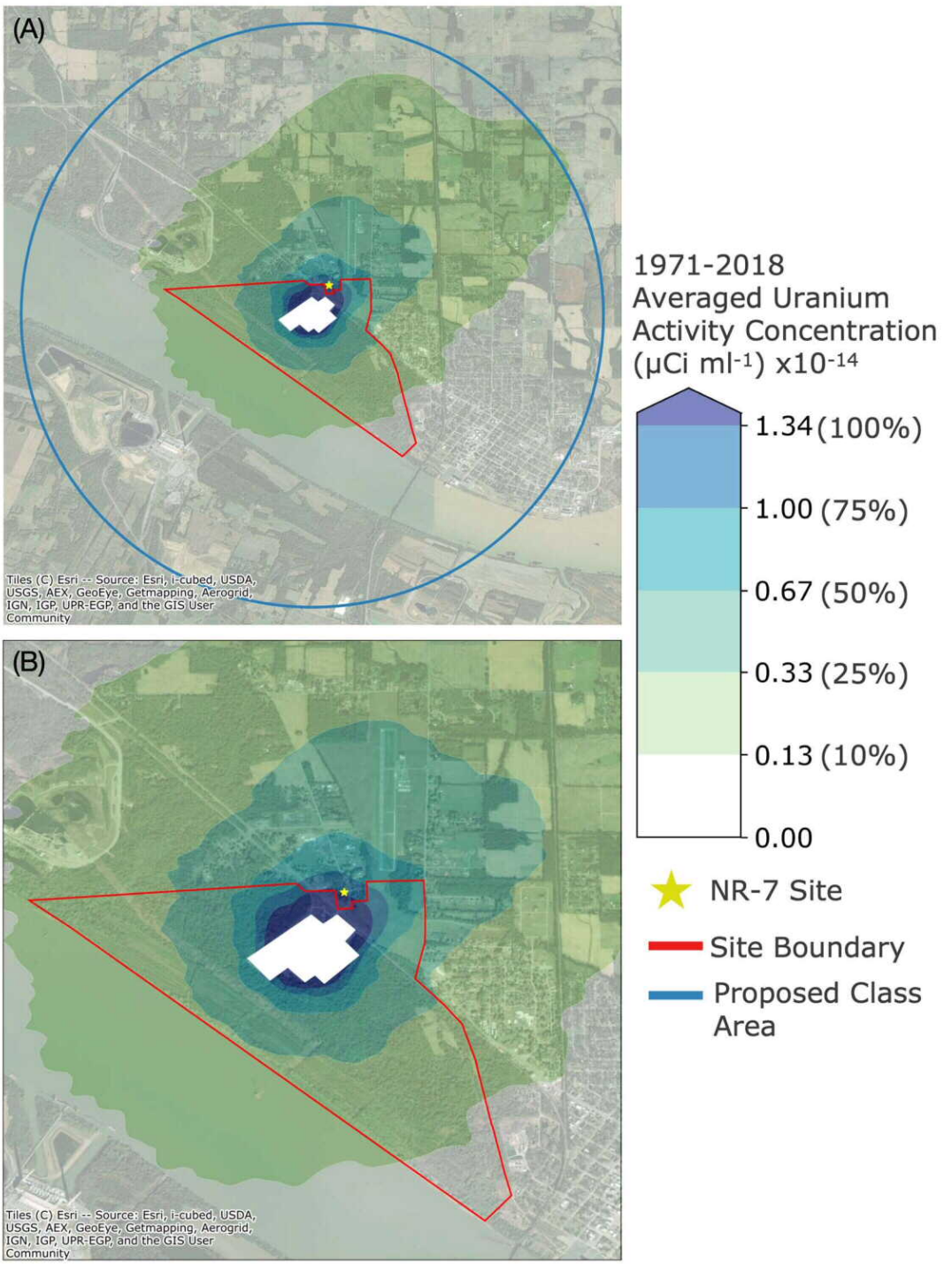

Figure 4-1: Modeled average uranium activity concentration in area surrounding MTW

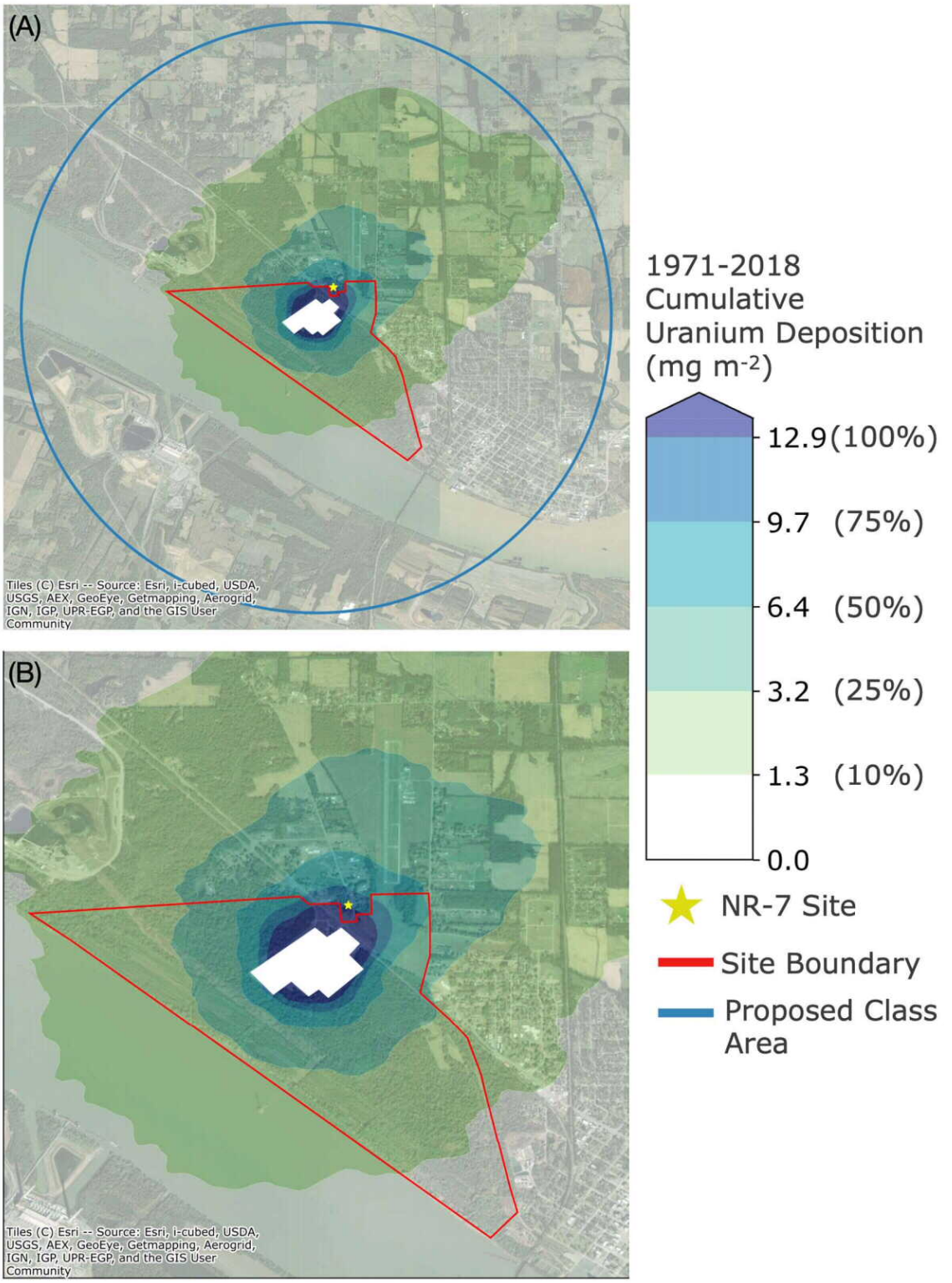

Figure 4-2: Modeled cumulative uranium deposition in area surrounding MTW

The modeled activity concentrations and cumulative deposition rates are highest closest to MTW and decrease rapidly with distance from MTW. The highest offsite activity concentrations and cumulative deposition rates occur in the vicinity of NR-7. The decrease with distance occurs less rapidly to the northeast of MTW as compared to other directions. This is consistent with the wind data used to drive the model. As the prevailing wind in the meteorological dataset is from the southwest, the prevailing wind blows toward the northeast. Obtaining higher activity concentrations and deposition rates to the northeast as compared to other directions is consistent with this data.

4.5 Comparison of Air Modeling to Air Monitoring

A comparison of modeled and monitored uranium concentrations at MTW's two offsite monitoring sites is shown in **Figure 4-3**. The results at each site are shown as boxplots. The monitored data collected between 1980 and 2017[52] are compared to modeled results for each year. For each year and site, a ratio of the modeled result to the monitored result was calculated at my direction. A ratio of 1 indicates the results were identical; a ratio of greater than 1 indicates that modeled concentrations were greater; and a ratio of less than 1 indicates that monitored concentrations were greater.

For each site, the ratios over the years evaluated is displayed in the boxplot. The central line of the boxplot indicates the median value and the edges of the boxes indicate the first and third quartile values. The whiskers extending beyond the boxes indicate 1.5 times the interquartile length (i.e., the distance between the first and third quartile values). As an example, if the interquartile length is 2, the length of the whiskers would be 3. The 1.5 times interquartile length is commonly used in statistics to identify outliers with values beyond the whiskers being considered as such. These outlier values are plotted individually in **Figure 4-3**.

Based on my experience, the ratios obtained demonstrate that the model is performing well and within expectations. As noted in federal regulations, "irreducible" uncertainties stemming from conditions that may not be explicitly accounted for in the model (such as the turbulence of the velocity field) associated with Gaussian plume models may be responsible for variations in concentration of up to +/-50 percent, so differences between modeled and monitored values within a factor of 2 are expected as a result of these irreducible uncertainties. "Reducible" uncertainties, such as imperfect characterization of emissions data and explicitly represented meteorology, imperfect characterization of model physics and formulation, and uncertainty ranges in the measurements themselves, also add uncertainty.[53] At both offsite stations, the median value of the ratio is greater than 1, indicating that modeled values are higher than

[52] Data were available in 1979-1982 and 1987-2017. While data were available from 2018 and onward, MTW operated only partially in 2018 and was then in ready-idle state thereafter. Accordingly, only those years for which data were available and MTW was actively producing UF_6 were considered. Due to uncertainty regarding when NR-7 moved during 1987, results for that monitor station during that year are not included in this comparison analysis. Uranium air monitor data in 1979 were only partially available, as results for Station 6 were available in the 1984 Environmental Impact Appraisal but results for NR-7 were not (see NRCADAMS071162). Uranium air monitor data in 1988 were also only partially available, as results for NR-7 were available in the 1995 Environmental Assessment but results for Station 6 were not (see NRCADAMS071049). Uranium air monitor data for 1983-1986 were not located. For 1980-1982, 1989-1993, 2000-2003, and 2010-2014, annual values were readily available. For other years, the average value was based upon the weekly values for each station and year.

[53] 40 CFR Part 51, Appendix W. 2017. Guideline on Air Quality Models. Vol. 82, No. 10. January 17. Available at: https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. Accessed November 10, 2023.

monitored values. This median ratio is 2.8 at Site 6 and 1.6 at NR-7.[54] The differences from a ratio of unity are within expectations given the model uncertainties as discussed above. In summary, the ratios demonstrate that the model is reliably (and conservatively) predicting observed concentrations, which increases my confidence in the model results to a reasonable degree of scientific certainty.

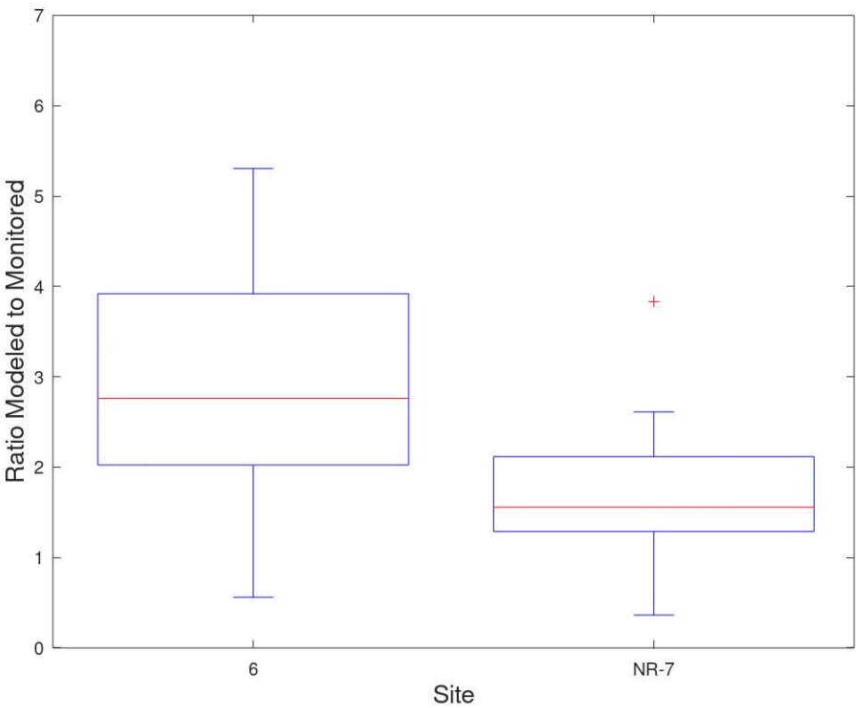

Figure 4-3: Distributions of modeled to monitored uranium concentrations at MTW's offsite monitor locations[55]

[54] The location of NR-7 changed in 1987. The ratio presented for NR-7 was calculated using the original location of NR-7 prior to 1987 and the new location of NR-7 after 1987. The year 1987 was not included in this calculation because the exact time during that year when NR-7 was moved is unknown. The original location of NR-7 is approximate.

[55] Site 6 has one ratio (24) beyond the extent of the figure and is not shown for legibility.

5. AFFIRMATIVE OPINIONS

5.1 Air Monitoring is Robust and Reliable

The air monitoring data for the MTW Facility is robust and reliable. Not only is there broad spatial coverage, but the monitors operate continuously and are checked weekly assuring that there is reliable temporal data as well. Moreover, the observed monitoring patterns align with the modeling results, demonstrating a clear correlation: as one moves away from the MTW boundary, the concentrations of uranium and other radionuclides rapidly decrease. These points are more fully detailed below.

5.1.1 Air Monitoring Program has Broad Spatial and Temporal Coverage

The combination of MTW and IEMA monitoring provides broad spatial and temporal coverage. The MTW monitoring provides monitors close to the Facility and in the direction of the prevailing winds while the IEMA monitoring provides monitoring data throughout Metropolis as demonstrated in **Figures 3-12 and 3-13**. This combination of multiple monitors with broad spatial coverage provides sufficient information to characterize radioactivity concentration patterns. In addition, the extended time range over which monitoring has been conducted (which covers the majority of MTW's operational history) provides sufficient information to evaluate how radioactivity patterns have changed over time. As noted in Section 3.5, MTW conducted gum paper fallout sampling until 1977, and has conducted continuous ambient air monitoring from 1977 to the present. IEMA has conducted radioactivity monitoring since at least 1996 through the present.

5.2 IEMA Air Monitoring is Independent of MTW

The IEMA air monitoring is conducted by the State of Illinois independent of MTW's monitoring. IEMA's independent monitoring demonstrates a rapid decrease in total alpha activity concentrations as the distance from MTW increases. This pattern generally aligns with uranium activity concentration pattern observed in the MTW monitoring network (i.e., decrease in uranium activity concentration as the distance from MTW increases). Thus, the IEMA data helps to validate the MTW data by providing another independent data set that confirms similar air quality patterns and trends.

5.3 Air Monitoring Data Indicate that Concentrations of Radionuclides Decrease Rapidly with Distance from MTW

Figure 5-1 shows annual concentrations of uranium based on MTW monitoring results averaged across all years without missing data, 1998-2018. As one moves away from MTW, airborne concentrations of uranium rapidly decrease. The highest offsite concentration is at NR-7, which has a long-term average concentration of 8.5×10^{-15} µCi/ml.

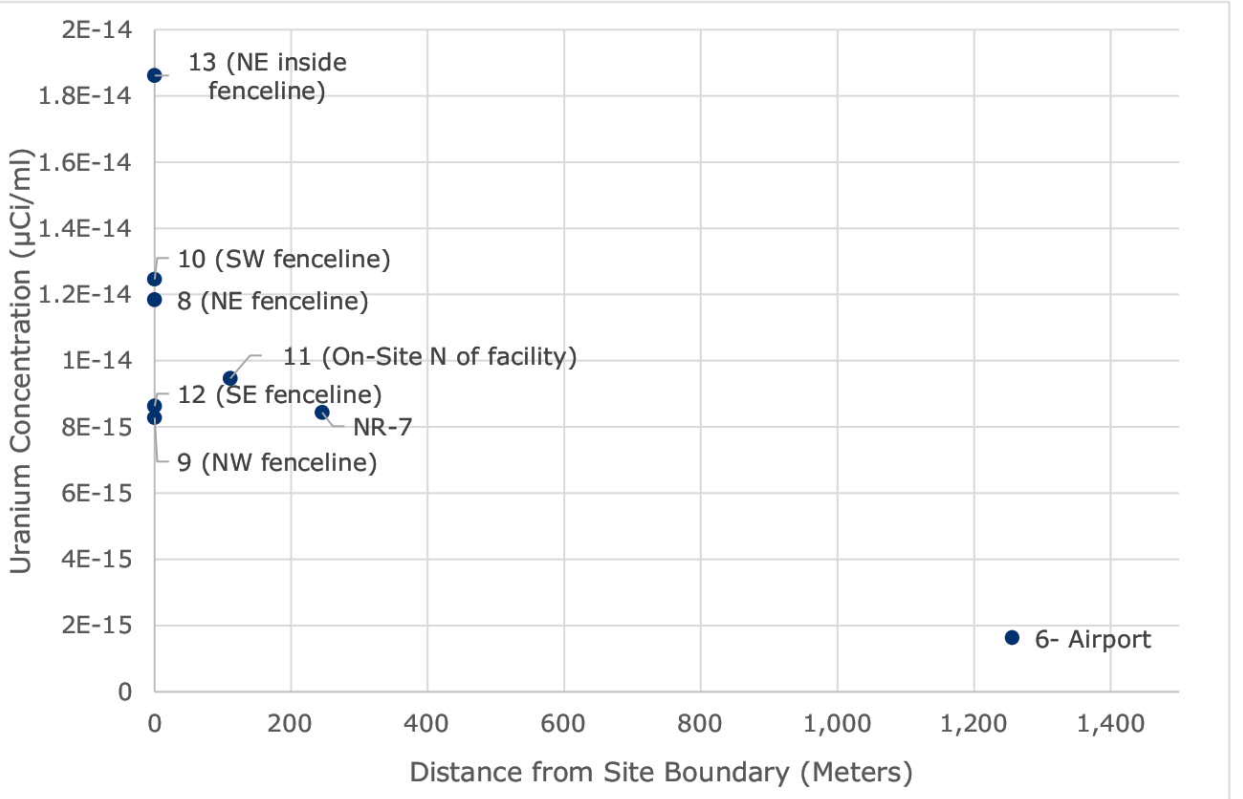

Figure 5-1: Ambient air concentrations of uranium near MTW based on long-term MTW data (1998-2018)

Figure 5-2 shows estimated total alpha based on IEMA monitoring results for the Metropolis Airport, NR-7, North Ave, and the Water Treatment Plant from years 1996-2013. These monitors were chosen since they were the only monitors with consistent data for a period longer than six years. Similar to the MTW data, the IEMA data show that concentrations decrease with distance from MTW.

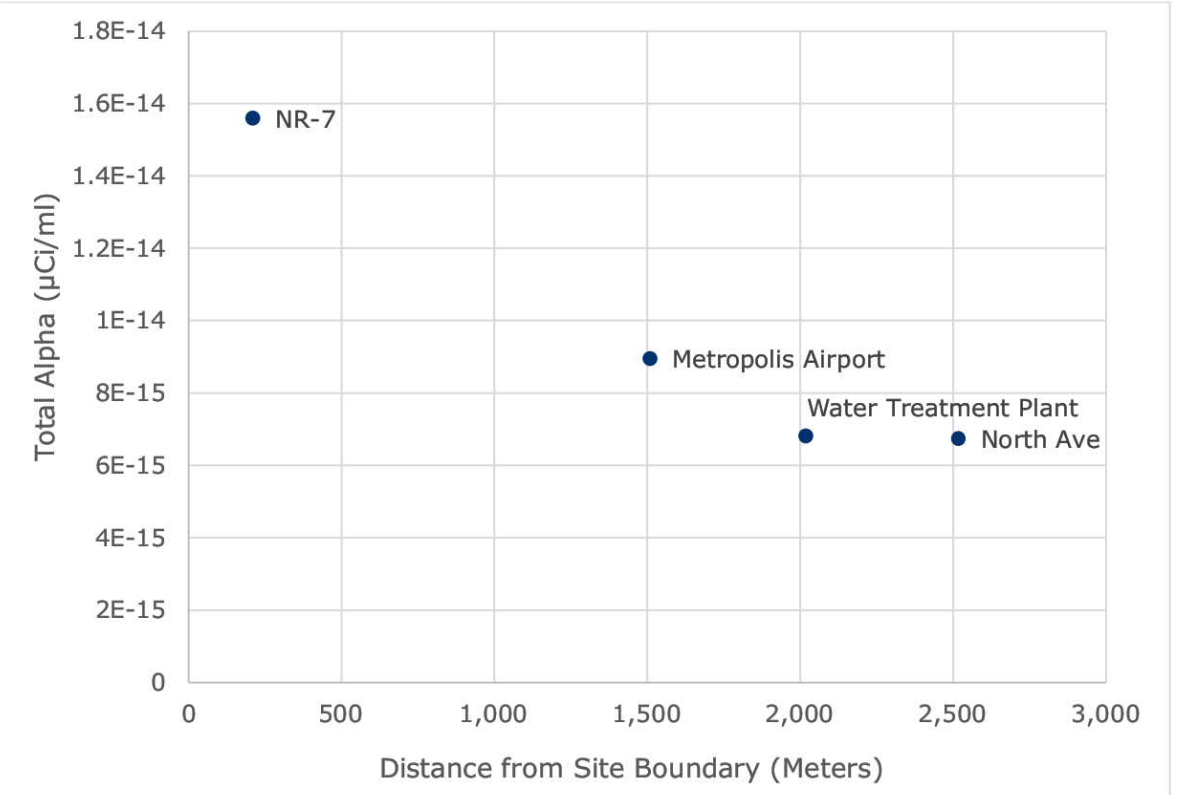

Figure 5-2: Ambient air total alpha activity concentration based on long-term IEMA data (1996-2013)

5.3.1 Air Monitoring Data has Detected Unplanned Releases

Due to its broad spatial and temporal coverage, the air monitoring has detected unplanned airborne releases from MTW, validating the usefulness of these monitors. In 2003, both MTW monitors and IEMA monitors detected an unexpected release from MTW involving UF_6 gas during the preparation of starting a second fluorination operating train within the Feed Materials Building.[56] The detection of this unexpected release by both MTW and IEMA monitoring programs underscores the reliability of the monitoring network and provides a mechanism for ensuring that radiologic impact of airborne releases from MTW are captured in the data.

5.4 The Decrease in Measured Concentrations with Distance is Consistent with Modeled Concentrations that One Would Expect if Emissions were from MTW

Both the air monitoring and the air modeling show a consistent pattern with radiological activity concentration decreasing with distance from MTW. Specifically, MTW air monitoring shows uranium activity concentration decreasing with distance from MTW, and IEMA air monitoring shows alpha activity concentration decreasing with distance from MTW. As discussed in Section 4, air dispersion modeling also shows that uranium activity concentration decreases with distance from MTW. Based on both monitoring and modeling data, NR-7 is the most exposed residential/offsite location. This consistency in radiological activity concentration patterns

[56] Honeywell Metropolis Works. 2004. Investigation Report of Uranium Hexafluoride Release on December 22, 2003. February 13. Available at: https://www.nrc.gov/docs/ML0526/ML052640427.pdf Accessed November 14, 2023.

between the modeling and the monitoring helps to confirm the reliability of both methods for assessing airborne impacts.

5.5 Nearest Resident is the Most Exposed Residential/Offsite Location

The nearest resident (i.e., NR-7) is the residential/offsite location that is most exposed from airborne radiological emissions from MTW. This opinion is based on monitoring data, modeling results, and prevailing winds. As noted in Section 3.5, both MTW and IEMA measure their highest offsite readings at NR-7. In addition, the AERMOD modeling discussed in Section 4 shows that the highest residential offsite impacts occur at NR-7, with offsite concentrations and deposition decreasing rapidly with distance from MTW. Dr. Auberle reached a similar conclusion: "In general, the greatest contamination occurred near Honeywell at locations north of the facility." Dr. Auberle's modeling shows a total deposition at NR-7 of over three times the highest deposition modeled at any one of the 19 Plaintiff addresses, which is consistent with the results of my deposition model. Finally, as evident from the wind roses in Section 3.1, the predominant winds near MTW are from the southwest. Since NR-7 is located northeast of MTW, it is in the predominant downwind direction.

5.6 Air Dispersion Model is Reliable and Conservative

The air dispersion modeling conducted under my supervision and direction is reliable and conservative (i.e., health protective). Not only have I addressed several issues regarding Dr. Auberle's modeling (see Section 6.1), but I have also compared the results of my modeling to available monitoring data. Based on that comparison, the model predicts patterns that are similar to the monitoring (i.e., decreasing concentration with distance from MTW with highest impacts in the downwind direction). The model also tends to estimate uranium concentrations that are higher than monitored values at offsite locations near the facility (i.e., NR-7, Airport). Thus, the model is conservative and is expected to predict concentrations, on average, that are higher than actual measured concentrations. This suggests that the fugitive emissions sources that Dr. Auberle claims are absent from his modeling are either non-existent or so negligible that they do not materially impact offsite concentrations.

6. REVIEW OF DR. AUBERLE'S OPINIONS

I reviewed a report provided by Plaintiffs entitled "An Analysis of the Atmospheric Transport and Impacts of Emissions from the Honeywell Specialty Materials Metropolis Works Facility, Metropolis, Illinois". The primary author of the report is Dr. William Auberle, although the report includes attachments prepared by other experts, including:

- A report by Dr. Paul Rosenfeld at Soil / Water / Air Protection Enterprise (SWAPE) entitled "Expert AERMOD Technician Report Evaluating Total Uranium Deposited from the Honeywell Facility Located in Metropolis, Illinois" (Attachment D to Dr. Auberle's report, dated September 1, 2023)
- A report by Dr. Bernd Franke entitled "CAP88-PC Dose Calculations in the Metropolis Case" (Attachment E to Dr. Auberle's report, dated October 2, 2020)
- A second report by Dr. Bernd Franke entitled "Emissions of Radioactive Materials from the UF_6 Production Plant at Metropolis, Illinois: Screening Calculations with CAP88-PC Version 4.1" (Attachment F to Dr. Auberle's report, dated September 22, 2023)

For purposes of this report, when I refer to "Dr. Auberle's report" or "Dr. Auberle's opinions", I am referring to his entire report, including the attachments outlined above that were prepared by other experts.

6.1 Dr. Auberle's Air Dispersion Modeling

A comparison of the modeling performed by Dr. Auberle and my modeling discussed in Section 4 reveals a number of differences in source locations, parameters, and emission rates. Although there are a number of discrepancies, the model outputs obtained by Dr. Auberle appear similar to the model results discussed in Section 4, so the material impact of these discrepancies is limited. Nonetheless, in this section I summarize the key differences in Dr. Auberle's modeling and my modeling.

6.1.1 Dr. Auberle's Modeling Source Parameters and Locations

A comparison of stack heights indicates that Dr. Auberle and I used the same stack heights, with the exception of the stack height increase to unit 1_49 at the end of 2013. However, I identified a number of differences between my model and Dr. Auberle's in prescribed stack velocities, exhaust temperatures, and diameters. There are three differences in these parameters that appear to be systemic in Dr. Auberle's modeling.

First, a review of Dr. Auberle's model input files indicates that stacks that were modeled with horizontal orientation were all set to an exhaust velocity of 2 m/s. The AERMOD User Guide does not endorse this treatment of horizontal point sources, and it contradicts best modeling practices. Section 3.2.2.4 of the AERMOD User Guide instructs users to input the actual stack parameters, including the actual exit velocity, as if the release were a non-capped vertical point source.[57]

Second, a number of sources were assigned a temperature of 68 °F in Dr. Auberle's modeling. This would be an appropriate temperature to use if these sources had no independent thermal buoyancy, but rather any heat in the plumes is from the buildings' comfort heating and cooling

[57] EPA. User's Guide for the AMS/EPA Regulatory Model (AERMOD) Section 3.2.2.4, Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_userguide.pdf. Accessed November 14, 2023.

systems. Based on my site visit, I concluded that many of the buildings with air effluent sources at MTW did not have effective interior climate control; interior building temperatures are hot during the summer and cold during the winter. AERMOD permits modeling exhaust at the external atmospheric ambient temperature by prescribing a temperature of "0" rather than room temperature.[58]

It is possible that sources may be emitting at temperatures greater than ambient if process waste heat is captured in the effluent. This increase will vary from source to source and depend on factors such as an effluent point's location, proximity to process equipment, ventilation within the buildings, and outside meteorological conditions. These increases are difficult to quantify. I also note that modeling higher stack temperatures would increase effluent buoyancy and, in general, result in lower modeled concentration and deposition totals. Given these considerations, it is my opinion that modeling with ambient stack temperature is appropriate to reflect the lack of comfort heating and cooling while conservatively recognizing the inability to quantify possible increases from waste heat capture.

Third, in addition to the differences in stack parameters, there are also differences in the locations of the stack between the models. Most differences in stack locations are on the order of tens of meters. The location difference for one stack is much larger. Source 1_11 (Drum Cleaning Dust Collector) is located in the central area of MTW, which is the location I used in my modeling. In Dr. Auberle's modeling, this same source was located over 250 meters away, along the southeastern fenceline of MTW.

6.1.2 Dr. Auberle's Meteorological Data

Review of Dr. Auberle's AERMET surface files indicates that the Bowen ratio is varied on an annual basis. A recommended approach in the AERSURFACE User Guide is to "determine moisture conditions either seasonally or monthly."[59] Dr. Auberle does not follow this generally accepted best practice in his modeling. Within a given year, precipitation conditions can vary. A site can experience abnormally wet conditions for portions of the year and abnormally dry conditions for other portions of the same year. Using a monthly or seasonal determination as recommended by EPA ensures these variations are captured in the meteorological record.

A review of Dr. Auberle's meteorology versus precipitation data recorded at the Paducah Airport also indicates Dr. Aubele's 2014-2018 precipitation analysis is incorrect. Dr. Auberle treated 2014 as having wet conditions, 2015 as having dry conditions, 2016 as having average conditions, 2017 as having wet conditions, and 2018 as having wet conditions. However, the annual precipitation totals at the Paducah Airport from 2014 through 2018 were 46.81 inches, 58.63 inches, 52.10 inches, 48.72 inches, and 55.82 inches, respectively. For the trailing 30 years (1989-2018), Dr. Auberle reported a 30th percentile total of 42.71 inches and a 70th percentile total of 55.57 inches. As noted in Section 4.3.7, the recommended approach is to treat the lowest 30 percent as dry, the highest 30 percent as wet, and the middle 40 percent as average. Based on this climatology, 2014 should have been treated as average (instead of wet),

[58] EPA. 2023. User's Guide for the AMS/EPA Regulatory Model Section 3.3.2.1. October. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_userguide.pdf. Accessed November 14, 2023.
[59] EPA. 2020. User's Guide for AERSURFACE Tool Section 3.2.8. February. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aersurface/aersurface_ug_v20060.pdf. Accessed November 14, 2023.

2015 as wet (instead of dry), and 2017 as average (instead of wet). In other words, Dr. Auberle's classifications are incorrect in three of the five years.

Dr. Auberle modeled meteorological data for five separate time periods; the earliest time period was 1975-1979 and the latest time period was 2014-2018. A known deficiency with older meteorological data is the lack of availability of 1-minute resolution data; archives of 1-minute resolution data only extend as far back as 1998 and not all stations with the data currently available have the data available in the most distant past years. As noted above, records processed through AERMET without 1-minute resolution data generally have a greater number of calm wind hours which are disregarded by AERMOD. A review of Dr. Auberle's meteorological data confirms that the older files do in fact contain a higher number of calms. The number of calm hours in each of Dr. Auberle's meteorological files is listed in **Table 6-1** below.

Period	Number of Calm Hours	Percentage of Calm Hours
1975-1979	7,829	17.9%
1981-1985	5,569	12.7%
1995-1999	7,959	18.2%
2005-2009	1,762	4.0%
2014-2018	221	0.5%

Table 6-1: Summary of calm hours in Dr. Auberle's meteorological files

If wind directions or speeds changed significantly over the decades, then capturing the change of climatological wind directions or speeds in the modeling by using older data might be warranted notwithstanding the more frequent occurrence of calm hours in the older data. But for the Paducah Airport station used in both Dr. Auberle's modeling and the modeling reported in Section 4 of this report, the changes to wind direction and speed with time are negligible. **Figure 6-1** displays wind roses generated from Dr. Auberle's AERMET files for the periods 1975-1979 (Dr. Auberle's oldest meteorological data) and 2014-2018 (Dr. Auberle's newest meteorological data). The overall pattern between the two wind roses is the same. Both periods show southwesterly winds as the most frequently occurring wind direction. The earlier period has winds most frequently occurring between 195-205 degrees; in the later data the mode has shifted slightly westward to 215-225 degrees. Additionally, the average wind speeds between the two periods are similar, with the 1975-1979 data indicating a 3.2 m/s average, and the 2014-2018 data a 3.3 m/s average. The two wind roses feature similar directions and speeds overall and use of the earlier wind data requires accepting a larger number of calm observations. Since the changes in wind profiles are minor and minimization of calm hours is critical to producing a robust AERMOD modeling output, and given EPA's concerns regarding the adequacy of standard data without the addition of 1-minute data,[60] the use of more recent meteorological data is preferable and consistent with accepted scientific practice, even for modeling of historical emissions.

Finally, it is noted that the wind rose based on Dr. Auberle's data for 2014-2018 shown below, and the 2017-2021 wind rose shown in Section 3.1.5 and used to produce the modeling discussed

[60] EPA. 2013. "Use of ASOS meteorological data in AERMOD dispersion modeling." March 8. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/20130308_met_data_clarification.pdf. Accessed November 17, 2023.

in Section 4, are highly similar with good agreement in finer details. Consequently, the differences between the wind data produced under my direction and wind data from earlier years are similarly small.

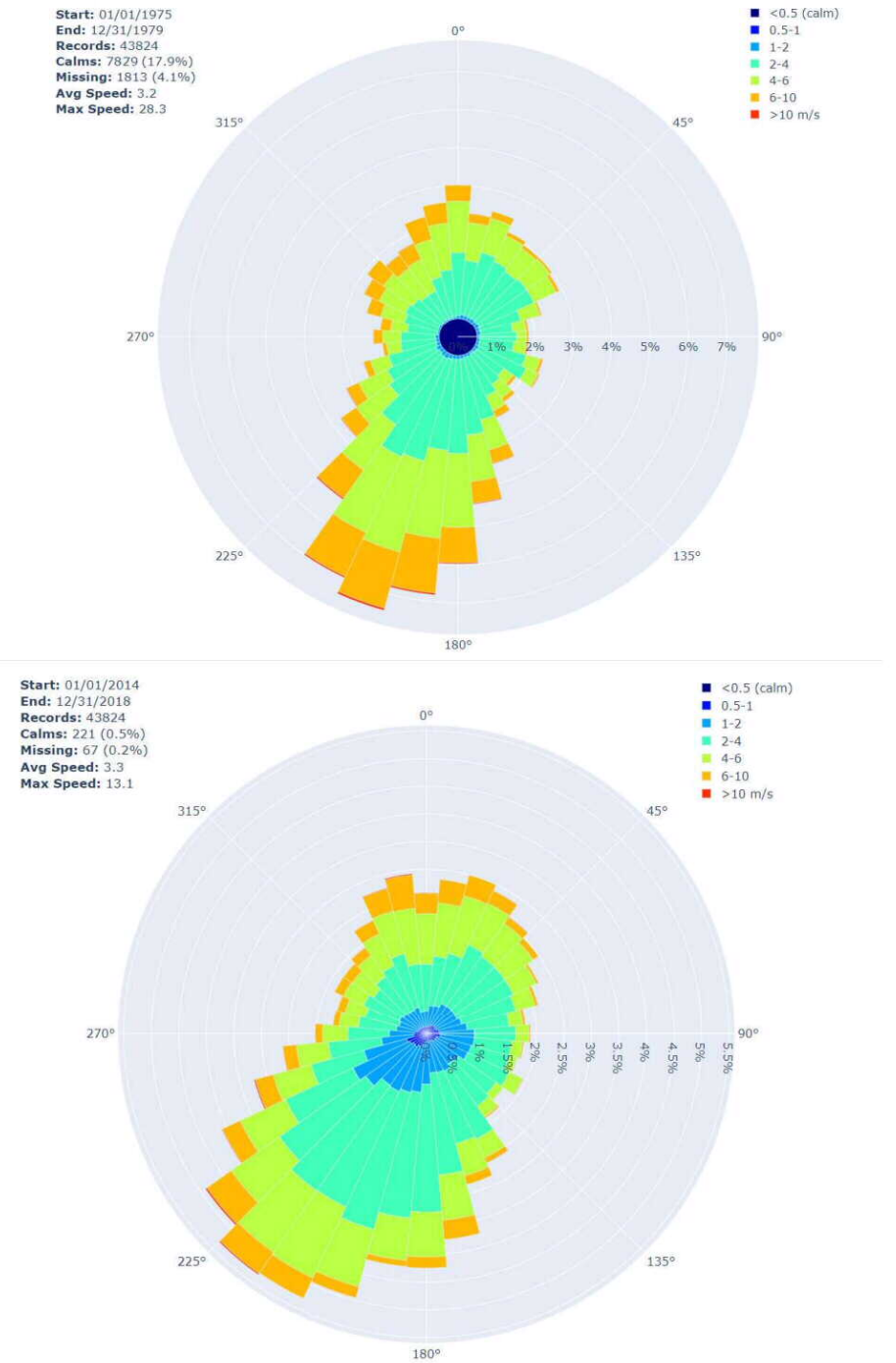

Figure 6-1: Wind roses based on Dr. Auberle's meteorological data for 1975-1979 (top) and 2014-2018 (bottom)

6.1.3 Dr. Auberle's Emissions

Dr. Auberle's report fails to provide sufficient information needed to reproduce and thereby fully understand emission rates for many of the sources included in the model.

For several years, Dr. Auberle's report utilizes emission rates that are inconsistent with data available in environmental reports submitted by MTW in support of license renewal applications. One such instance concerns the 1995 Environmental Assessment, which provides emission rates for stacks active from 1989-1994.[61] Emission rates contained in the emission file produced by Plaintiffs in connection with Dr. Auberle's report ('MTW Emissions 1975-2018.xlsx') do not match the emissions rates from the 1995 Environmental Assessment, which covers years 1989-1994. In some instances, the emission rates used in Dr. Auberle's model are much greater than the emission rates in the 1995 Environmental Assessment.

In addition to finding inconsistencies with reported values, inconsistencies were also noted in Dr. Auberle's calculated values. For example, calculations in Dr. Auberle's workbook 'MTW Emissions.xlsx' suggest that total emissions from stack number 1-3, the 'Drum Cleaner Dust Collector', in calendar year 1979 should be roughly 0.0023 Ci. However, this calculated value is inconsistent with expected Ci emissions for the same source when applying Dr. Auberle's provided specific activity conversion rates to the mass emitted from this source in 1979, which was 2.3 kilograms (kg).[62] Using the specific activity (Ci/pound) provided by Dr. Auberle in 'Conversion of Emissions Rates of U.docx', the total emissions from the Drum Cleaner Dust Collector in 1979 should be roughly 0.0008 Ci. In this instance, Dr. Auberle has vastly overestimated emissions, again with no explanation of calculation methodology. This calculation methodology is employed in Dr. Auberle's emissions from 1976 to 1986.

Specific activity refers to the radioactivity per unit mass of a particular substance. Dr. Auberle produced a Microsoft Word file entitled 'Conversion of Emission Rates of U.docx', which contains a specific activity of 0.00015 Ci per pound of uranium.[63] Dr. Auberle applied this conversion to Ci per year (Ci/yr) emission rates in 'Exhibit B Honeywell AERMOD Inputs.xlsx' to develop grams per second (g/s) emission rates for each of the sources modeled. Within 'Conversion of Emission Rates of U.docx', the calculation is labeled "Conversion of Emission Rates of U-238 at Honeywell MTW", so it appears that Dr. Auberle incorrectly assumed that U-238 is the only uranium isotope generated at MTW. As referenced in Section 3.3.2, the International Atomic Energy Agency explains:

> *"The International Atomic Energy Agency (IAEA) defines uranium as a Low Specific Activity material. In its natural state, it consists of three isotopes (U-234, U-235 and U-238)."*[64]

[61] AlliedSignal, Inc. 1995. Environmental Assessment for Renewal of Source Material License SUB-256 Docket 40-3392. April. NRCADAMS071049.
[62] Allied Chemical Company. 1984. Environmental Impact Appraisal for Renewal of Source Material License No. SUB-256 Docket No. 40-3392. May. NRCADAMS071162.
[63] Conversion of Emission Rates of U.docx
[64] International Atomic Energy Agency. Depleted Uranium. Available at: https://www.iaea.org/topics/spent-fuel-management/depleted-uranium. Accessed November 2, 2023.

Additionally, MTW's "SOP Methods for Determining Airborne Radioactivity" confirms these three isotopes to be present in natural uranium.[65] Dr. Auberle's report appears to ignore the presence of U-234 and U-235 isotopes in the uranium processed by MTW in its conversion.

6.1.4 Comparison of Modeling Results

Although several issues were noted in the previous sections, the patterns of deposition appear to be similar between the results presented here and those in Dr. Auberle's report.

In general, results at a given receptor are higher in the modeling presented in my report than those in Dr. Auberle's report. As discussed in the previous section, Dr. Auberle's modeling used older meteorology with a greater number of calm wind readings, and AERMOD is unable to calculate deposition and concentration values for these hours. All else being equal, it is expected that a record containing a fewer number of calm hours would produce higher deposition totals, since the model is able to calculate deposition for a greater number of hours. There are other differences in Dr. Auberle's modeling and my modeling that may also account for the differences.

6.1.5 Conservative Nature of Modeling

Dr. Auberle opines that his model underestimates uranium impacts from MTW, but—except as described above—much of the basis of this opinion is unfounded. For example, Dr. Auberle states that his model underestimates uranium impacts because the model only includes stacks/vents but not fugitive emission sources. Dr. Auberle's opinion that there are additional sources of emissions that are not captured in the modeling or air monitoring is speculation. For example, MTW operates much of the Facility under negative pressure, which limits the potential for fugitive emissions from seasonal opening of large building ventilation panels and open doorways (two sources of potential fugitive emissions identified by Dr. Auberle). In addition, vegetation surrounding the Facility has been demonstrated to reduce airborne particulates (see further discussion in Section 8), which Dr. Auberle does not consider.

Most importantly, Dr. Auberle does not compare his modeled (AERMOD) results to air monitoring results. A comparison to monitored results is an important part of EPA's evaluation to determine preferred models,[66] so when both monitored and modeled data are available, a sensible performance check is to compare the two datasets. When such a comparison is performed, as shown in **Figure 6-2**, Dr. Auberle's modeling contains periods with both overprediction and underprediction of uranium concentrations at the two offsite MTW monitors (NR-7 and Station 6 [Airport]), depending on the site examined and period.

Since Dr. Auberle's modeling was performed using averaged emissions values from each decade, the concentration results produced by Dr. Auberle also represent values averaged over a decade. Accordingly, for each of NR-7 and Station 6, the results obtained by Dr. Auberle for each of those locations were compared to the available monitoring data for each decade. The monitoring data is the same as that used in Section 4.5, and the concentrations are obtained from Dr. Auberle's modeling. The monitoring data is recorded in microcuries while Dr. Auberle's model results are in micrograms, so the conversion factor used by Dr. Auberle to convert curies to grams was

[65] Metropolis Works. Standard Operating Procedure – License Related Determination of Airborne Radioactivity. March 19, 2018. HONSteward-0070424.
[66] 40 CFR Part 51, Appendix W. 2017. Guideline on Air Quality Models. Vol. 82, No. 10. January 17. Available at: https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. Accessed November 10, 2023.

employed in reverse to compare to the monitored concentrations. Values were evaluated for four decades/periods (1981-1990; 1991-2000; 2001-2010; 2011-2017) at each site. For site NR-7, since Dr. Auberle's receptor at NR-7 represented the post-1987 location, not the pre-1987 location, the analysis was performed for 1988-1990 data.

Values for each decade/period are plotted in **Figure 6-2**. As in Section 4.5, a ratio of 1 indicates equal modeled and monitored results; a ratio greater than 1 indicates higher modeled results, and a ratio of less than 1 indicates higher monitored results. The comparisons show ratios which are sometimes higher than 1 but sometimes lower than 1, so the model is not systematically underestimating concentrations, as asserted by Dr. Auberle. However, ratios indicate modeled and monitored results are generally within a factor of 2, indicating acceptable model performance given the constraints discussed earlier.

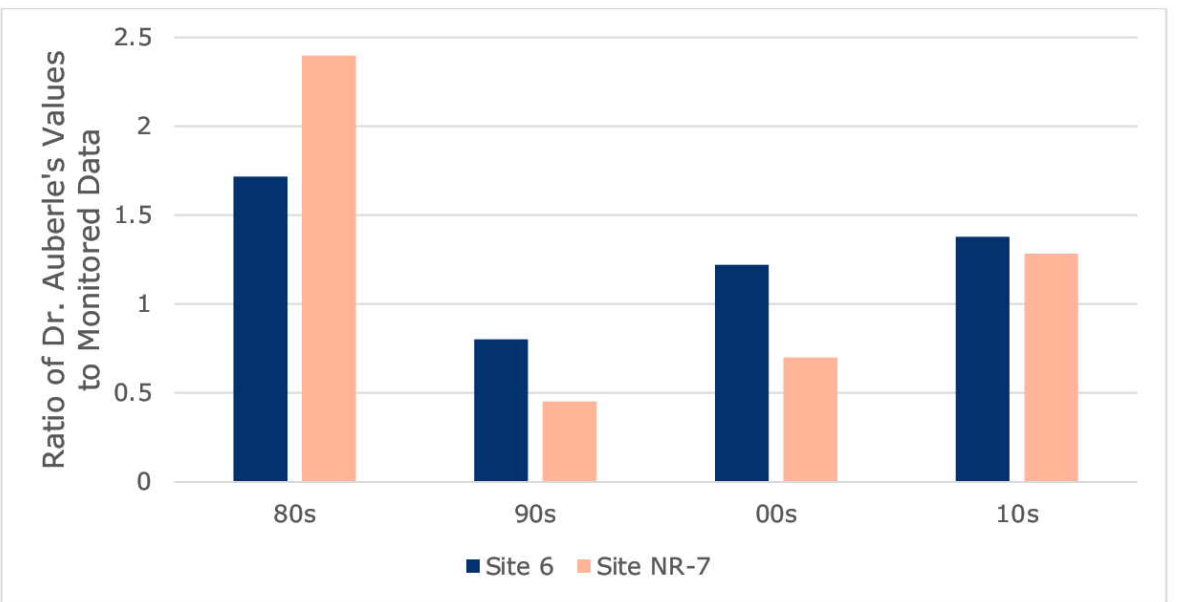

Figure 6-2: Comparison of Dr. Auberle's modeling to monitored uranium activity concentrations

In sum, when compared to the monitored data, Dr. Auberle's modeled results do not show consistent underprediction but a mix of cases where the modeled results are higher in some years and monitored results are higher in some years. Additionally, ratios of modeled and monitored data being consistently within a factor of approximately 2 indicate the model is performing acceptably and within expectations.

7. ALTERNATIVE SOURCES OF EMISSIONS

There are a number of alternative sources of uranium and alpha radiation in the area. Some of these are described below.

7.1 Paducah Gaseous Diffusion Plant

The Paducah Gaseous Diffusion Plant (PGDP) is located in Paducah, Kentucky across the Ohio River and approximately four miles south of MTW (**Figure 7-1**). The plant is owned by the Department of Energy (DOE). The plant began supplying enriched uranium for national defense purposes in 1952 and later provided nuclear fuel rods for power plants. Uranium enrichment activities ceased in 2013. Current site missions include environmental cleanup, waste disposition, depleted uranium conversion, deactivation and decommissioning of the former uranium enrichment facilities, and long-term stewardship. The PGDP is located on about 3,500 acres of land. The former plant operations area occupies 750 acres of land that is fenced and secured.[67]

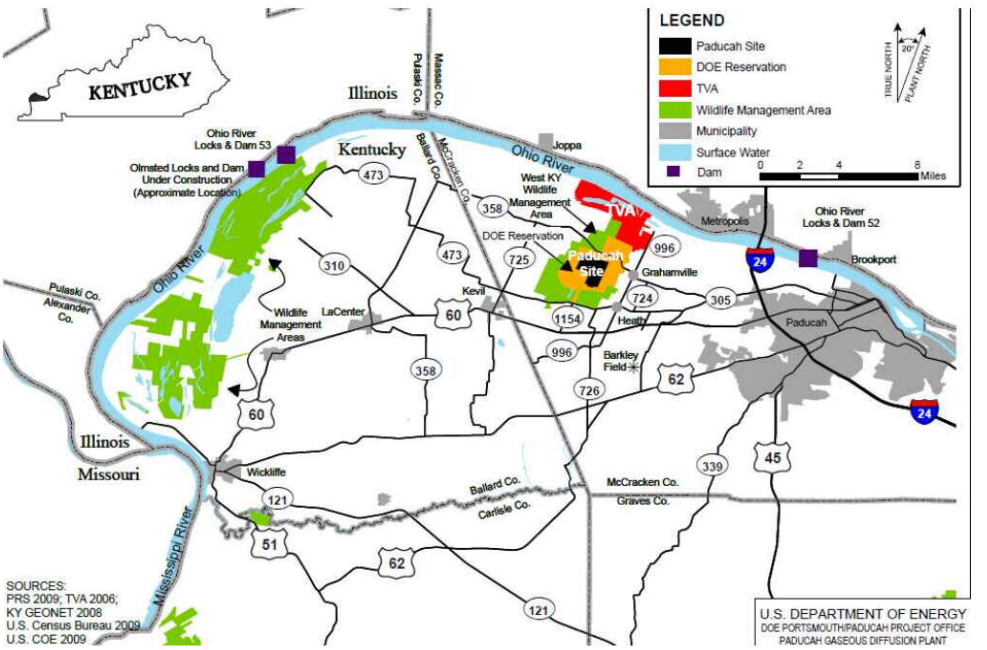

Figure 7-1: Paducah site location[68]

More than five decades of plant operations resulted in the generation of hazardous wastes, radioactive wastes, mixed (hazardous and radioactive) wastes, and other wastes. Releases of these wastes contaminated soil, groundwater, surface water, and sediment at the plant and beyond the plant boundary. Sampling and periodic monitoring by DOE have identified various contaminants in soil, surface water, sediments, and groundwater on the site and beyond the site

[67] EPA. 2023. Superfund Site: Paducah Gaseous Diffusion Plant. Available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0404794#Status Accessed November 15, 2023.

[68] DOE. 2019. Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant. May. Available at: https://semspub.epa.gov/work/04/11133935.pdf Accessed November 15, 2023.

boundary. Contaminants of concern include trichloroethylene, polychlorinated biphenyls, technetium-99, uranium, thorium, and transuranic elements (e.g., plutonium and neptunium).[69]

The EPA listed the PGDP as a Superfund site on the National Priorities List in 1994. In 1998, the DOE, EPA, and the Kentucky Department for Environmental Protection (KDEP) entered into a Federal Facility Agreement for site cleanup activities.[67] The DOE plans to undertake additional site investigations and more cleanup actions to address environmental contamination through 2065. Due to the large amount of Superfund-related waste that will be generated from the decontamination and decommissioning of plant buildings and other cleanup activities, DOE plans to evaluate disposal options for site wastes, including the potential construction and operation of an on-site waste disposal facility in the 2030-2060 timeframe.

With uranium enrichment activities having ended, the following two major programs are operated by DOE at the Paducah Site: Environmental Management and Uranium Program.[70] The mission of the Environmental Management program is to characterize and dispose of waste stored and generated on-site in compliance with regulatory requirements and DOE Orders.

The major missions of the Uranium Program are to maintain safe, compliant storage of the DOE depleted uranium hexafluoride (DUF_6) inventory until final disposition, operate a facility for the conversion of DUF_6 to a more stable oxide and hydrofluoric acid, and manage associated facilities and grounds. A product of the uranium enrichment process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders. The mission of the DUF_6 Cylinder Program is to safely store the DOE-owned DUF6 inventory until its ultimate disposition. DOE has a cylinder management program that includes cylinder and cylinder yard maintenance, routine inspections, and other programmatic activities such as cylinder corrosion studies. The program maintains a cylinder inventory database that serves as a systematic repository for all cylinder inspection data.

The DUF_6 facility converts the inventory of DUF_6 to triuranium octoxide (U_3O_8), a more stable form of uranium that is suitable for disposal or reuse, and hydrofluoric acid sold for commercial use. Low levels of hydrofluoric acid off-gassed from the conversion process (hydrogen fluoride vapor) are captured by a primary and secondary caustic scrubber system. Emissions from oxide handling are controlled by a high-efficiency particulate air filter system. Air that is displaced during the filling and emptying of hydrofluoric acid storage tanks at the hydrofluoric acid storage and load-out area is vented through a dedicated scrubber system. The DUF_6 conversion facility operates under a KDEP air permit and has two emission points: the stack for the Conversion Building and the stack for hydrofluoric acid storage and load-out area.[71]

PDGP's annual environmental reports indicate substantial exceedances of the EPA reference values in the groundwater samples from PGDP solid waste landfills: e.g., in 2005 alpha activity by 353%, dissolved alpha by 313%, technetium-99 by 878%[72]; in 1995 the exceedance of reference values was reported for radon-222, technetium-99, uranium, gross alpha, and gross beta,

[69] EPA. 2023. Superfund Site: Paducah Gaseous Diffusion Plant. Available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0404794#Status Accessed November 15, 2023.
[70] DOE. 2017. 2017 Paducah Site Annual Site Environmental Report. September. Available at: https://www.energy.gov/sites/prod/files/2018/10/f56/2017-Paducah_ASER.pdf. Accessed November 11, 2023.
[71] Ibid.
[72] DOE. 2007. Annual Site Environmental Report for Calendar Year 2005. Page 9-12. August. Available at: https://pubdocs.pad.pppo.gov/Annual%20Site%20Environmental%20Report%20%28ASER%29/2005%20ASER/2005%20ASER.pdf. Accessed November 16, 2023.

although the detected values were not disclosed.[73] In 1988, radioactive contamination was found in the drinking water wells of residences near PGDP. In response, DOE began a cleanup program. In 2000, the US Governmental Accountability Office reported that DOE faced significant challenges in cleaning up the site and that it was doubtful that the cleanup would be completed as scheduled by 2010 and within the $1.3 billion cost projection.[74]

Several incidents at PGDP causing radioactive contamination have been reported over the years. For example, on April 30, 2013, during unloading a UF_6 cylinder a pressure spike on the cylinder occurred, causing some of the heel material daughter products (thorium-234 and protactinium-234m) in minute particulate form to become suspended. The ensuing jetting of the cylinder then drew this particulate through the valve into the pigtail. During the pigtail disconnection, the particulate was released into the atmosphere and was the source of the contamination.[75] Atmospheric uranium hexafluoride releases were documented in 1955 and 1974.[76]

In 2010 a group of landowners settled a lawsuit for $1.75 million running from 1997 over allegations that water leaks from the PGDP devalued property, contaminated land and well water, and caused adverse health effects.[77] In 2016, Lockheed Martin operated PGDP from 1984 to 1999 has agreed to pay $5 million to the federal government to settle lawsuits alleging violation of the Resource Conservation and Recovery Act by failing to identify and report hazardous waste produced and stored at the facility, and failing to properly handle and dispose of the waste.[78]

Radionuclide sources at the Paducah Site evaluated in 2017 included the: Northwest Plume Groundwater Treatment System; Northeast Plume Containment System Treatment Units; DUF_6 Conversion Facility; C-709/C-710 Laboratory Hoods; and Seal Exhaust/Wet Air Group.

The site's most recent Five-Year Review was reported in 2018. EPA determined that four of the cleanup actions are "Protectiveness Deferred" (i.e., a protectiveness determination of the remedy cannot be made until further information is obtained). DOE invoked dispute resolution on the determinations and identification of additional work to be performed. DOE, EPA, and KDEP are working together through the Federal Facility Agreement (FFA) dispute resolution process to reach an agreement on the information necessary to re-evaluate the protectiveness of the four cleanup actions.[79]

[73] DOE. 1997. Paducah Site Annual Report For 1995. January. Available at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/073/28073831.pdf. Accessed November 16, 2023.
[74] US Government Accountability Office. 2004. Nuclear Waste Cleanup: DOE Has Made Some Progress in Cleaning Up the Paducah Site, but Challenges Remain. April 1. Available at: https://www.gao.gov/products/gao-04-457. Accessed November 16, 2023.
[75] World Information Service on Energy (WISE) Uranium Project. 2021. Available at: https://www.wise-uranium.org/eopusec.html. Accessed November 16, 2023.
[76] Govinfo.gov. 1996. Health and Safety: Environmental Oversight of Classified Federal Research (Testimony, 03/12/96, GAO/T-RCED-96-99). Available at: https://www.govinfo.gov/content/pkg/GAOREPORTS-T-RCED-96-99/html/GAOREPORTS-T-RCED-96-99.htm Accessed November 20, 2023
[77] AP. 2010. Cited by WISE Uranium Project. April 20. Available at: https://www.wise-uranium.org/eopusec.html. Accessed November 16, 2023.
[78] DOJ. 2016. Lockheed Martin Agrees To Pay $5 Million To Settle Alleged Violations Of The False Claims Act And The Resource Conservation And Recovery Act. Available at: https://www.justice.gov/usao-wdky/pr/lockheed-martin-agrees-pay-5-million-settle-alleged-violations-false-claims-act-and. Accessed November 20, 2023
[79] EPA. 2023. Superfund Site: Paducah Gaseous Diffusion Plant. Available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Cleanup&id=0404794#Status

7.2 Coal-Fired Power Plants

Considering that some trace elements in coal are naturally radioactive, coal-fired plants can be a significant source of radioactivity. These radioactive elements include uranium, thorium, and their numerous decay products, including radium and radon. Uranium concentration in solid combustion wastes (fly ash, bottom ash, and boiler slag) is approximately 10 times the concentration in the original coal.[80] According to the USGS CoalQual database[81], uranium concentrations can reach 4.62 ppm, 8.91 ppm, and 62 ppm in some coals mined in Illinois, Kentucky, and Missouri, respectively. A typical US 1,000-MW coal-fired plant may release 5.2 tons of uranium (containing 74 pounds of uranium-235) and 12.8 tons of thorium annually.[82]

A 1,750-MW coal-fired power plant, the TVA Shawnee Power Plant, is located near Paducah along the Ohio River approximately 2 miles from Metropolis and approximately 1.6 miles from MTW (**Figure 7-2**). The plant has been in operation since 1953.[83] A 1,099.8 MW coal-fired power plant, the Joppa Steam Power Plant, is located approximately 8 miles from Metropolis and approximately 6.2 miles from MTW (**Figure 7-3**). The power plant operated since 1953 until its closure in September 2022.[84] Both of these plants would contribute to radioactive contamination on the adjacent areas to the plants.

[80] USGS. 1997. Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance. U.S. Geological Survey Fact Sheet FS-163-97. October. Available at: https://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.pdf. Accessed November 11, 2023.
[81] USGS. 2023. Coal Quality (COALQUAL) Database. Available at: https://ncrdspublic.er.usgs.gov/coalqual/. Accessed November 11, 2023.
[82] Gabbard, A. 1993. Coal combustion: Nuclear resource or danger. Oak Ridge National Laboratory Review. Vol. 26, No. 3&4. Available at: https://www.nrc.gov/docs/ML1002/ML100280691.pdf. Accessed November 11, 2023.
[83] Power Technology. 2023. Power plant profile: Shawnee Fossil Plant, US. November 10. Available at: https://www.power-technology.com/data-insights/power-plant-profile-shawnee-fossil-plant-us/?cf-view. Accessed November 11, 2023
[84] Power Technology. 2021. Joppa Steam Power Plant, US. December 13. Available at: https://www.power-technology.com/marketdata/joppa-steam-power-plant-us/. Accessed November 11, 2023.

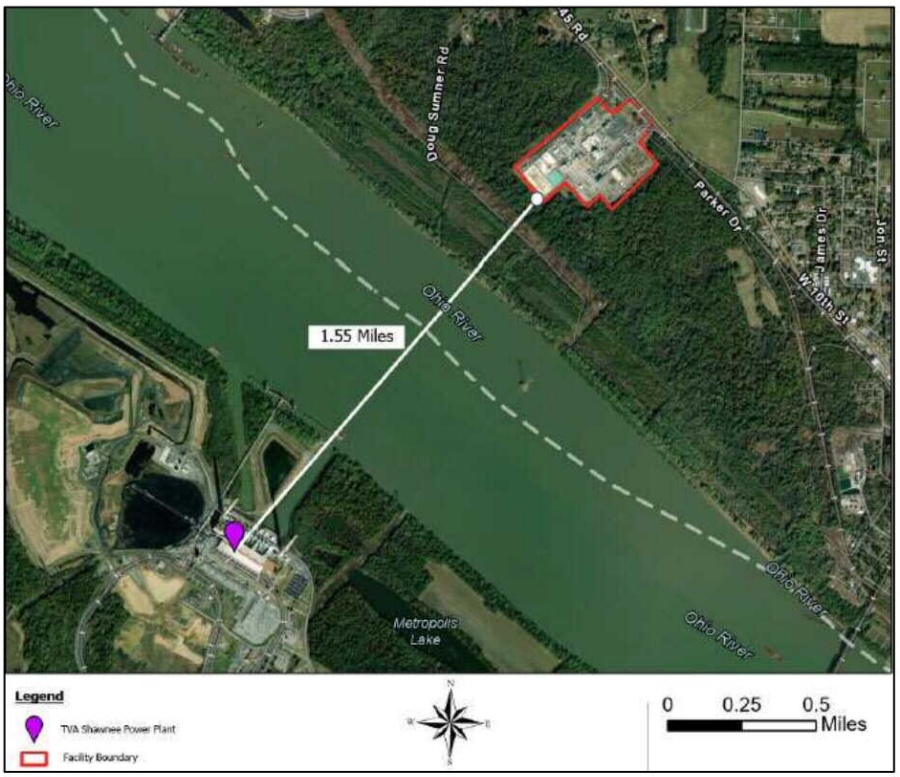

Figure 7-2: Location of TVA Shawnee Power Plant

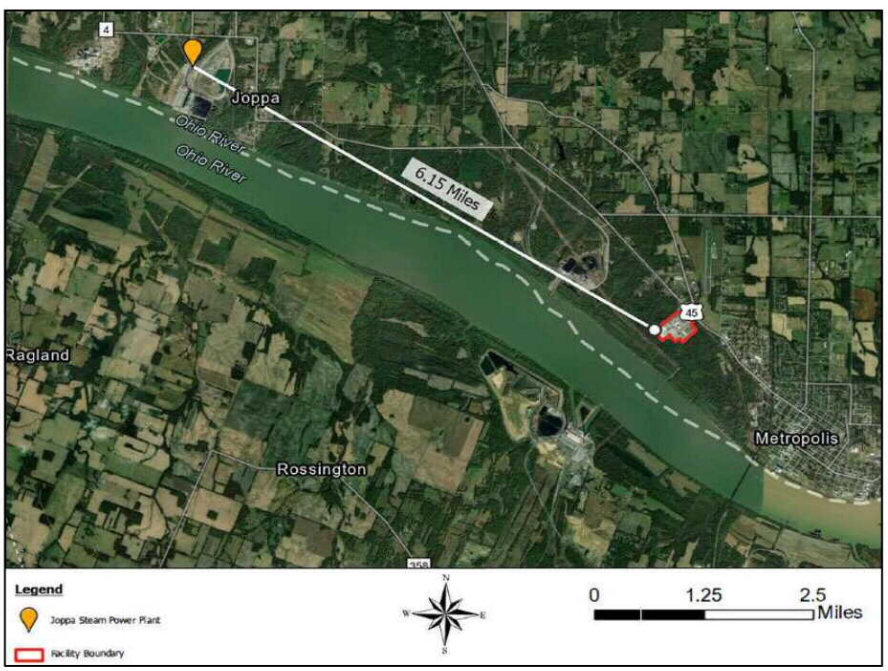

Figure 7-3: Location of Joppa Steam Power Plant

7.3 Cook Coal Terminal

Cook Coal Terminal, the busiest US inland coal terminal,[85] is located within approximately 2 miles of Metropolis and approximately 1.2 miles from MTW (**Figure 7-4**). It has 20 million tons of annual capacity throughput and 500,000 tons of coal storage capacity. The terminal conducts loading (5,000 tons per hour, ground to barge) and unloading (6,600 tons per hour, rail to barge, rail to ground) operations, which includes weighing, blending, and storing coal.[86] It occupies 1,600 acres.[87] Uranium concentration in some coals may exceed its average concentration in the Earth's crust (2.76 ppm[88]), so within the years of operation, dust emissions from the terminal could contribute to background uranium concentrations.

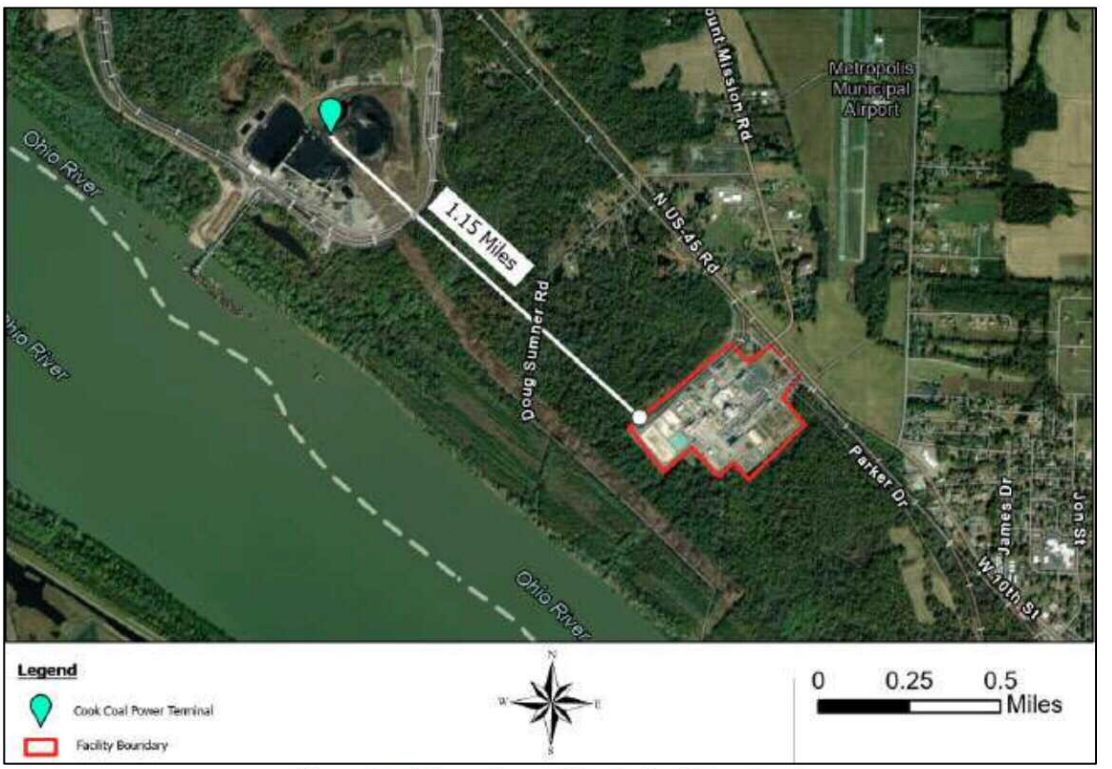

Figure 7-4: Location of Cook Coal Terminal

7.4 Orano TLI UF_6 Cylinder Service Center

Orano TLI (former Daher-TLI) UF_6 Cylinder Service Center (UCSC) is located in Kevil, Kentucky (7017 Paducah Road, Kentucky 42056), approximately 11 miles southwest of Metropolis (**Figure 7-5**). The facility has been operating since 2013. It conducts storage, washing, recertification, and disposal of natural and depleted UF_6 cylinders. UCSC has over 5 acres of storage capacity for 1,000 full cylinders, 400 heeled cylinders, and 600 empty cylinders. The facility's operation

[85] UMWA. 2023. Cook Coal Terminal – Local Union 2463. Available at: https://umwa.org/news-media/journal/cook-coal-terminal/. Accessed November 11, 2023.
[86] Union Pacific. 2023. Cook Coal Terminal (American Electric Power). Available at: https://www.up.com/customers/bulk/ports-docks/cook/index.htm. Accessed November 11, 2023.
[87] UMWA. 2023. Cook Coal Terminal – Local Union 2463. Available at: https://umwa.org/news-media/journal/cook-coal-terminal/. Accessed November 11, 2023.
[88] Herring, J.S. 2012. Uranium and Thorium Resources. In: Meyers, R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. Available at: https://doi.org/10.1007/978-1-4419-0851-3_21. Accessed November 11, 2023.

implies truck transportation of radioactive cargo.[89] Although the potential radiation doses to the general population from transportation of radioactive materials are usually low,[90] UCSC operation may contribute the background radiation.

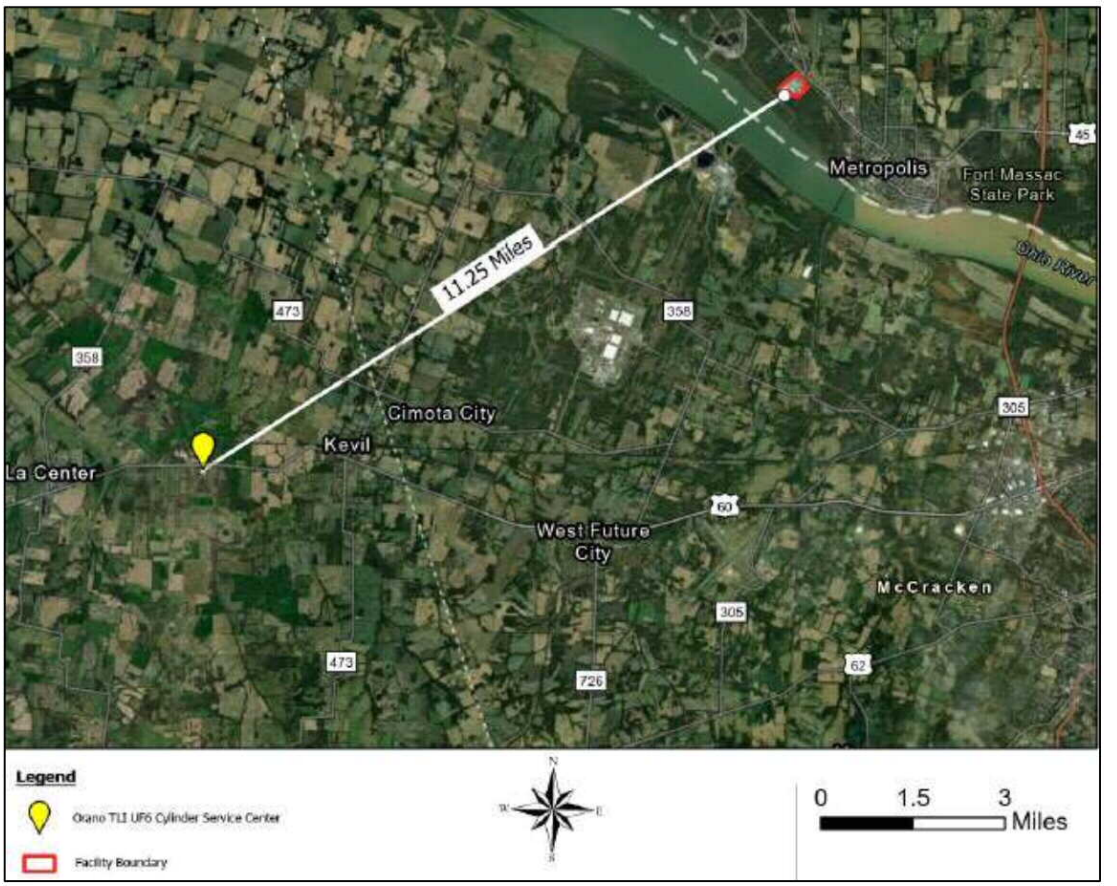

Figure 7-5: Location of Orano TLI UF_6 Cylinder Service Center

7.5 Other Anthropogenic and Natural Sources of Uranium

Phosphate fertilization is the main source of uranium contamination of agricultural land, primarily due to impurities in the phosphate rock used for fertilizer manufacture. As an example, in Germany, the use of phosphate fertilizer from 1951 to 2011 has resulted in a cumulative application of approximately 14,000 tons of uranium on agricultural land, corresponding to an average cumulative loading of 1 kg of uranium per hectare.[91] Uranium concentrations in fertilizers have been found to correlate positively with phosphorus compounds in the Mississippi River drainage system.[92]

[89] Orano TLI. 2023. Services. Available at: http://tliusa.com/index.php/88-services. Accessed November 11, 2023.
[90] DOE. 2001. Transportation Impact Assessment for Shipment of Uranium Hexafluoride (UF_6) Cylinders from the East Tennessee Technology Park to the Portsmouth and Paducah Gaseous Diffusion Plants. Available at: https://www.nrc.gov/docs/ML1127/ML112720424.pdf. Accessed November 11, 2023.
[91] Schnug, E.; Lottermoser, B. G. Fertilizer-Derived Uranium and Its Threat to Human Health. *Environ. Sci. Technol.* **2013**, *47* (6), 2433–2434. https://doi.org/10.1021/es4002357.
[92] Spalding, R. F.; Sackett, W. M. Uranium in Runoff from the Gulf of Mexico Distributive Province: Anomalous Concentrations. *Science* **1972**, *175* (4022), 629–631.https://doi.org/10.1126/science.175.4022.629.

Metropolis is located in the area of New Albany Shales, an organic-rich geologic formation in the Illinois Basin. It was found that the uranium concentration in the road cut outcrop in the New Albany Shales exceeds its crustal abundance almost tenfold while the road construction promoted weathering of the adjacent black shales and mobilized uranium via the acid rock drainage mechanism (sulfide oxidation at an oxygenated environment and subsequent migration to surface waters).[93,94]

These anthropogenic and natural sources of uranium may contribute to background uranium levels around MTW.

7.6 Other Sources of Alpha Radiation

Typical alpha emitters include radium-226, radon-222, uranium-238, plutonium-236, thorium-232, and polonium-210.[95] Some geological sources of radon and thorium near Metropolis are noted as follows.

7.6.1 Radon

Figure 7-6 shows that the geological radon potential near Metropolis is relatively low on both the Illinois and Kentucky sides of the Ohio River but notably grows upstream which, considering radon solubility, may affect radon water concentrations near Metropolis.

[93] Tuttle, M. L. W. et al. Weathering of the New Albany Shale, Kentucky: II. Redistribution of Minor and Trace Elements. *Applied Geochemistry* **2009**, 24 (8), 1565–1578. https://doi.org/10.1016/j.apgeochem.2009.04.034.
[94] Parviainen, A.; Loukola-Ruskeeniemi, K. Environmental Impact of Mineralised Black Shales. *Earth-Science Reviews* **2019**, 192, 65–90. https://doi.org/10.1016/j.earscirev.2019.01.017
[95] Collum, B. 2 - Radiation, Nuclear Facilities, *Woodhead Publishing*, **2017**, https://doi.org/10.1016/B978-0-08-101938-2.00002-7

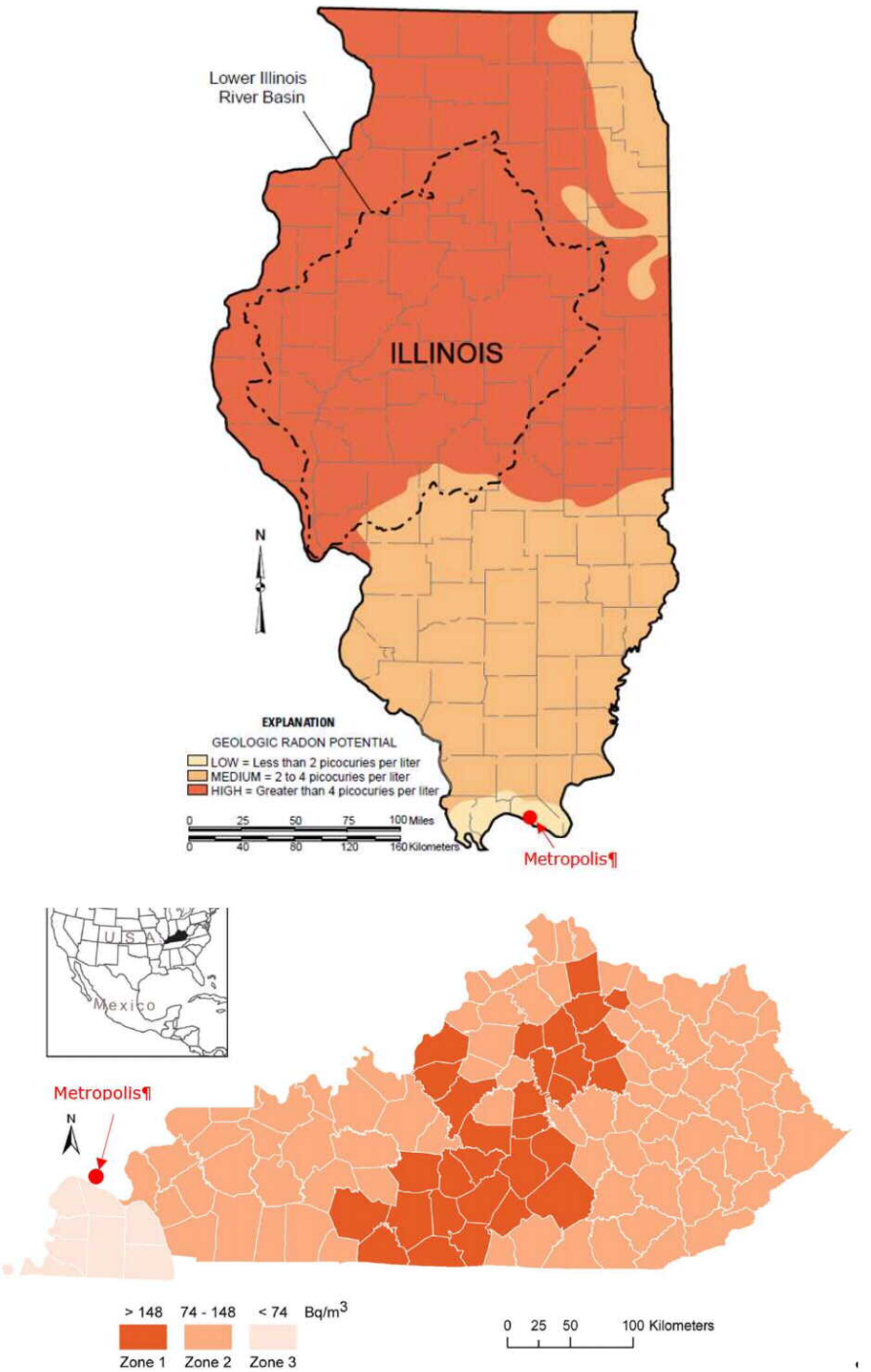

Figure 7-6: Geologic indoor radon potential in Illinois[96] (top) and Kentucky[97] (bottom)

[96] USGS. 2001. Uranium and Radon in Ground Water in the Lower Illinois River Basin. Available at: https://pubs.usgs.gov/wri/2001/4056/wrir01_4056.pdf. Accessed November 11, 2023.
[97] Haneberg, W. C. et al. A Geologically Based Indoor-Radon Potential Map of Kentucky. *GeoHealth* **2020**, *4* (11), e2020GH000263. https://doi.org/10.1029/2020GH000263

7.6.2 Thorium

Within approximately 51 km (32 miles) of Metropolis in Hardin County lies Hicks Dome, a dome-shaped structure approximately 14.5 km in diameter (**Figure 7-7**).[98] Drilling into the dome at a depth of 490 m (1,607 ft) revealed thorium concentrations ranging from 0.007 to 0.18 percent thorium dioxide (ThO_2).[99] An airborne radiometric survey conducted in 2019 showed a substantial thorium concentration anomaly at Hicks Dome, which may contribute to background levels of alpha radiation near MTW.[100]

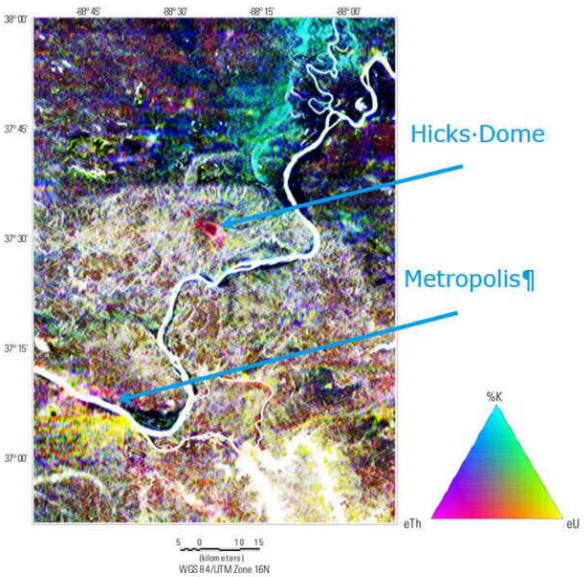

Figure 7-7: Hicks Dome location and airborne radiometric map

[98] Ibid.
[99] USGS. 2009. Thorium Deposits of the United States - Energy Resources for the Future? Available at: https://pubs.usgs.gov/circ/1336/pdf/C1336.pdf. Accessed November 11, 2023.
[100] USGS. 2020. Hicks Dome Radiometric Data. Available at: https://www.sciencebase.gov/catalog/item/5e6c0b3fe4b01d5092638c95. Accessed November 11, 2023.

8. THE CLASS IS NOT SIMILARLY SITUATED

As discussed below, the potential exposures to individual people and individual properties from emissions from MTW is a function of location and varies widely depending on proximity to MTW and location in relation to prevailing winds, vegetation, and other factors.

8.1 Proximity to Different Sources Matters

Quantities of emissions from different emission sources do not alone determine impacts at a specific location. The proximity of each emissions source to the specific location under evaluation and meteorological conditions must also be considered. For example, an emissions source that has lower levels of emissions and is located very close to the location of interest may contribute more to impacts (e.g., levels of pollution in the air) than a larger emission source that is located farther away. Plaintiffs' experts did not evaluate any alternative sources of emissions in or near the proposed Class Area, nor did they consider that alternative sources of emissions located closer to areas of interest have a larger impact on airborne concentrations, even if the quantities of emissions from those emissions sources were smaller than emissions from MTW.

Due to variations in meteorological conditions, impacts due to emissions from MTW and other sources of radiation located in or near the proposed Class Area would vary both temporally and spatially throughout the proposed Class Area as does any contributions from MTW's emissions. As such, it is not possible to treat areas of concern as being uniformly impacted and only subject to emissions from MTW. An individualized inquiry as to proximity of each emissions source and meteorological conditions is required to determine impacts (if any) at a specific location.

8.2 Effect of Vegetation

Vegetation is known to improve air quality by removing various constituents from the air. Experimental studies in which generated fine diesel exhaust was passed through different types of vegetation (e.g., silver birch, yew and elder) in a wind tunnel have shown vegetation to be effective in filtering particles from the air.[101] For example, one study (Maher[102]) reported an overall decrease in the localized particulate concentrations due to the presence of young birch trees.

Multiple factors affect the deposition of particulates onto vegetation, including the height at which the emissions are released, the deposition velocity of the particulate, and the characteristics of the vegetation (i.e., the ability for the surface of the vegetation to adhere to the pollutant).[103]

[101] Huixia Wang, Barbara A Maher, Imad AM Ahmed, and Brian Davison. 2019. Efficient Removal of Ultrafine Particles from Diesel Exhaust by Selected Tree Species: Implications for Roadside Planting for Improving the Quality of Urban Air. *Environmental Science & Technology* *53* (12), 6906-6916 DOI: 10.1021/acs.est.8b06629

[102] Maher, B. A.; Ahmed, I. A. M.; Davison, B.; Karloukovshi, V.; Clarke, R. 2013. "Impact of Roadside Tree Lines on Indoor Concentrations of Traffic-Derived Particulate Matter" Environmental Science and Technology, 47: 13737-13744. Available at: https://doi.org/10.1021/es404363m

[103] Pugh, T. A. M.; MacKenzie, A. R.; Whyatt, J. D.; Hewitt, C. N. 2012. "The effectiveness of green infrastructure for improvement of air quality in urban street canyons" Environmental Science and Technology, 46, 7692-7699. Available at: https://doi.org/10.1021/es300826w

Litscheke and Kuttler[104] report that particle removal increases with deposition velocity, which increases substantially with particle size above 10 microns in diameter.

Removal efficacy varies due to vegetation coverage (greater coverage, greater removal), concentration of pollution, growing season (longer the growing season, the greater the removal efficiency), and the meteorological conditions (wind, humidity, and precipitation).

Since vegetation can inhibit the transport of particles and can also remove particles from the air, any assessment would need to understand how different vegetation would impact the transport of emissions from MTW and other sources in the area. Because there is a differing amount and type of vegetation throughout the proposed Class Area, the class is not similarly situated as it relates to how vegetation may inhibit the transport of emissions.

8.3 Housing Construction and Age

Housing construction, the age of the house, and heating and air conditioning can impact how particulates from the outside get into the house in different ways. There are likely different types of houses within the proposed Class Area.

For example, housing construction can affect the size and number of holes and cracks in the building envelope, which are the pathways for air to enter or exit the house. Older houses may have more gaps and leaks due to deterioration, poor insulation, or lack of sealing. Newer houses may have tighter envelopes due to better materials, techniques, and building codes.

Heating and air conditioning can affect the pressure difference between the indoor and outdoor air, which is the driving force for air to flow into or out of the house. Heating and air conditioning systems can create positive or negative pressure in the house, depending on the design, operation, and maintenance of the system. Positive pressure means that the indoor air is at a higher pressure than the outdoor air, and it pushes air out of the house. Negative pressure means that the indoor air is at a lower pressure than the outdoor air, and it pulls air into the house. The pressure difference can also vary depending on the weather conditions, the ventilation rate, and how the house is used (e.g., opening of windows and doors).

Heating and air conditioning can also affect the filtration and purification of the indoor and outdoor air, which can reduce or increase the amount of particulates that enter or exit the house. Heating and air conditioning systems can have filters or purifiers that remove particulates from the air before it enters or leaves the house. The effectiveness of the filters or purifiers depends on the type, size, and quality of the device, as well as the frequency and quality of the maintenance.

8.4 Impacts Are Not Distributed Uniformly

The proposed Class Area encompasses a 3-mile radius from MTW. The IEMA and MTW air monitoring data, as well as the air dispersion and deposition modeling presented in Section 4, indicate that offsite concentrations of radioactivity are not uniformly distributed, but instead vary with distance and direction from MTW. This is illustrated in **Figures 8-1 and 8-2**, which show

[104] Litscheke, T. and Kuttler, W. 2008. "On the Reduction of Urban Particle Concentrations by Vegetation - a Review" Meterologishe Zeitschrift, 17 (3): 229-240. Available at: https://www.researchgate.net/publication/228352471_On_the_reduction_of_urban_particle_concentration_by_vegetation_-_A_review

modeled average uranium activity concentration (1971-2018) and cumulative uranium deposition (1971-2018) at random residences within a 3-mile distance from MTW.[105] As indicated in **Figure 8-1**, the estimated average uranium activity concentration varies by a factor of 12.1 at these residential locations (maximum = 0.508 x 10^{-14} µCi/mL, minimum = 0.042 x 10^{-14} µCi/mL). As indicated in **Figure 8-2**, the estimated cumulative uranium deposition varies by a factor of 12.1 at these residential locations (maximum = 4.58 mg/m^2, minimum = 0.38 mg/m^2). In order to examine a set of receptors located at a similar distance from MTW, receptors within 50 meters of the 3-mile distance proposed for the Class Area were examined. For this purpose, the location of the Feed Materials Building was defined at the center point of MTW and distances measured from there. Even at the fixed distance, large variability in impacts is observed. The maximum and minimum values for concentration and deposition in this sub-population of receptors was determined. At the 3-mile proposed Class Area radius, the average uranium activity concentration varies by a factor of 3.2 (maximum = 0.116 x 10^{-14} µCi/mL, minimum = 0.036 x 10^{-14} µCi/mL), and the estimated cumulative uranium deposition varies by a factor of 3.2 (maximum = 1.04 mg/m^2, minimum = 0.33 mg/m^2).

[105] The center of the Plaintiffs' proposed Class Area was assumed to be at the center of MTW's Feed Materials Building.

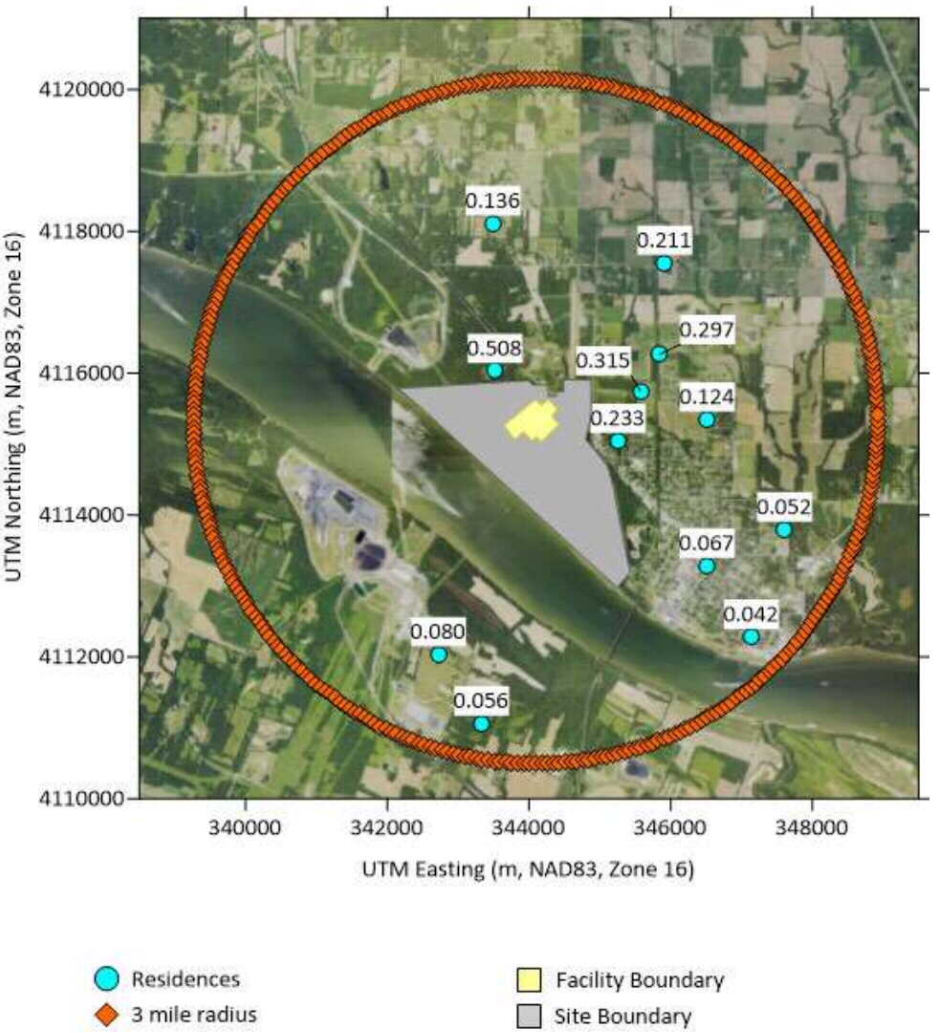

Figure 8-1: Long-term average modeled concentration (x10^{-14} microcuries per milliliter) at twelve residences randomly chosen within the proposed Class Area

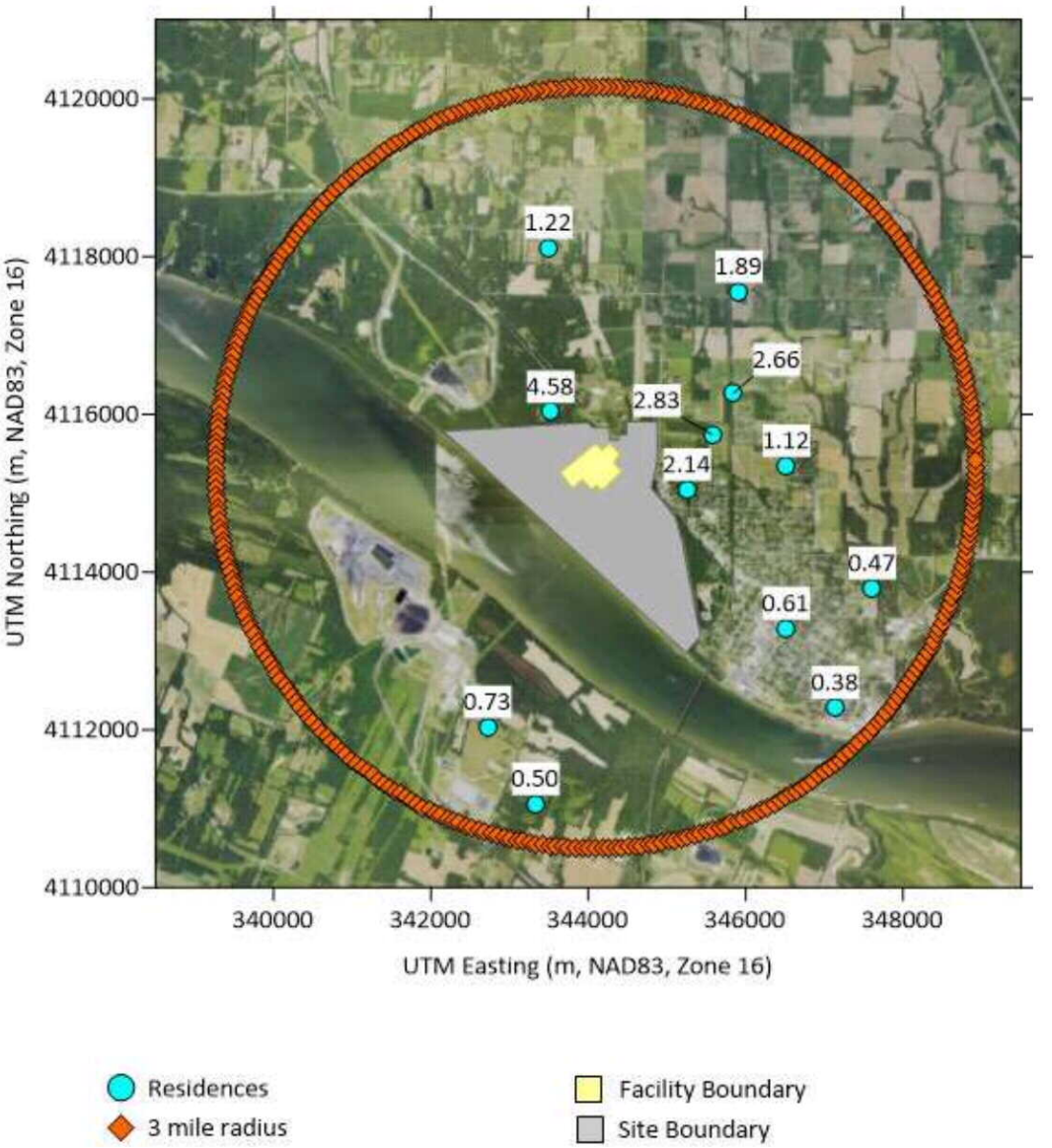

Figure 8-2: Long-term cumulative total deposition (milligrams per square meter) at twelve residences randomly chosen within the proposed Class Area

8.5 The Exposure of Each Individual Must be Assessed Individually

Similar to the discussion above, the level and duration of a plaintiff's exposure to emissions from MTW may vary depending on several factors; therefore, the exposure to pollutants for a group of plaintiffs must be individually assessed. These individual factors include: the proximity of the plaintiff to the source of pollution at any time; the frequency and intensity of an individual's contact with the polluted environment; and the personal and work history, habits and lifestyle of each plaintiff. These factors may affect the dose and the effect of the pollutants on each plaintiff.

APPENDIX A
CURRICULUM VITAE

RAMBOLL

ENVIRONMENT & HEALTH

SHARI BETH LIBICKI, PHD

Principal

Dr. Shari Beth Libicki has over 30 years of chemical fate and transport experience, as applied to managing greenhouse gas (GHG) emissions and estimating air emissions and dispersion from refineries, chemical processes, landfills, quarries and new developments. She is an expert on GHG evaluations for California Environmental Quality Act (CEQA) documents. She has conducted extensive air quality regulatory assessments for New Source Review/Prevention of Significant Deterioration (NSR/PRD) permitting. She has directed community monitoring programs under California's AB 617. Shari has lectured widely on evaluating climate change impacts for new developments and estimating chemical exposure for risk assessments. She currently serves as an Adjunct Professor in the Department of Chemical Engineering at Stanford University.

EDUCATION

PhD, Chemical Engineering, Stanford University, 1985
MS, Chemical Engineering, Stanford University, 1981
BSE, Chemical Engineering, University of Michigan, 1979

EXPERIENCE HIGHLIGHTS

Expert Support

- Served as an expert witness for a mass tort located in South America focused on a multi-metals refining facility. The main pollutant at issue was lead, and the emissions sources include mineral and metals processing equipment, including retorts, ovens, screens, and transport belts. The facility was heavily monitored for a variety of airborne metals and sulfur dioxide, and the engagement involved interpreting air monitoring data. Finally, the facility was located in a mountain valley, and we conducted computation fluid dynamic modeling to evaluate the ambient monitoring locations.
- Served as an expert witness evaluating the emissions from an ethylene oxide sterilizer. The opposing expert had asserted that a mass balance around the oxidizer could be used to estimate emissions. We were able to show that the information that the opposing expert was using was flawed and that the type of mass balance proposed could not be used to estimate ethylene oxide emissions.
- Served as an expert witness for a multiparty litigation where historical air quality in Haifa, Israel was at issue. We were able to create a database of all available air quality data in the

CONTACT INFORMATION

Shari Beth Libicki, PhD

slibicki@ramboll.com
+1 (415) 796.1933

Ramboll
2200 Powell Street
Suite 700
Emeryville, CA 94608
United States of America

region, and to clarify the regional contribution to local air quality.

- Served as an expert witness on a permit appeal for natural gas compression for use in marine vessels with the goal of reducing greenhouse gases from marine transport. At issue was the potential natural gas releases from the compression and expansion of natural gas.
- Served as an expert witness for a series of mass torts where plaintiffs alleged harm resulting from emissions from a flaring event at a refinery in Texas. There was nearly a decade of information from ambient air monitors sited in and around the refinery. In addition, there was monitoring information on emissions from the flare during the flaring event. We conducted detailed air dispersion modeling to assess the statistical distribution of exposure among hundreds of named plaintiffs. Issues centered around using discrete monitoring data and air dispersion modeling to evaluate impacts in the neighborhood.
- Assisted a chemical manufacturing plant evaluate neighborhood concentrations of ethylene oxide using a monitoring network and a windspeed/wind direction analysis to better understand source allocations. Worked with the facility to minimize ethylene oxide emissions and further reduce neighborhood concentrations.
- Served as an expert witness for several cases where plaintiffs alleged harm as a result of living near a waterway into which oil was released as a result of excessive rainfall at a refinery. Issues in the case included an evaluation of the cause of the release, emissions estimation, dispersion modeling, and an analysis of an extensive set of ambient air quality data.
- Reconstructed plumes from explosions using NOAA radar data from a refinery and chemical plant. The plume reconstruction allowed us to pinpoint the exact location of the plume as a function of time and informed the potential exposures by plaintiffs the plume.
- Evaluated the location of a plume after a fire at a refinery which resulted in a shelter in place order. The plume was reconstructed using a wide variety of evidence, including photographs, movies, and sophisticated air quality modeling.
- Served as an expert witness for a case where exposure to dust and diesel particulate from a quarry was alleged. The plaintiffs put microsensors on their houses to measure dust and posted the data on a public website. We were able to use the publicly available data to show that the dust in the neighborhood was not correlated with mining activities or blasting events. In addition, we estimated the emissions and dispersion of diesel particulate to show that the diesel particulate from mining operations was below a level of significance.
- Served as an expert witness in defense of claims of property diminution from fugitive dust emissions from an adjacent coke production facility. The work was conducted using nearby monitors that recorded PM_{10} concentrations before and after the establishment of the production facility. A meteorological analysis was also conducted that evaluated whether wind direction impacted measured PM_{10} concentrations. The case was further complicated by the presence of rail lines that transported large amounts of coal fines.
- Provided expert support in a case requiring reconstruction of emissions over a 70-year period from a specialty chemical manufacturer. Emissions estimation involved reconstructing historical processes and process controls and combining them with annual production records. The emissions estimates were used to assist in case settlement.
- Served as an expert witness in defense of a remediated wood treatment facility where historical dust emissions were alleged to have contaminated the neighborhood. The analysis included an evaluation of the various factors that would impact dust contamination including vegetation, rainfall, vehicle count, and meteorology.
- Provided technical support to attorneys on a litigation case where an accidental release of a particulate and liquid material from a refinery was alleged to have caused harm to thousands of plaintiffs. This included an engineering evaluation of the release quantity, meteorological data analysis, and an evaluation of dispersion and deposition of aerosols in complex and intervening terrain.
- Served as an expert witness evaluating PCB airborne emissions from process emissions and soil contamination from a PCB-producing facility. This included PCB manufacturing process

reconstruction since the beginning of PCB manufacturing, as well as an estimate of the amount of PCB emitted from fugitive dust from vehicles traveling over contaminated roads, and dust track-out.

- Served as an expert witness supporting the permitting efforts of a large landfill in Texas. Permit contestants alleged that the landfill gas collection system was improperly designed and was incapable of collecting landfill gas consistent with the requirements. The case included the use of surface methane measurements, odor complaint history, and well measurements to show that the landfill gas system was operating as designed.
- Provided expert assistance in estimating airborne emissions and onshore impacts from an offshore oil leak. Evaluation included reviewing monitoring data, data on emissions, meteorology, and the potential for dissolution and degradation.
- Served as an expert witness in a case where exposure to arsenic from the burning of CCA-treated wood was alleged. The case surrounding the potential for a lineman to be exposed to arsenic from CCA-treated utility poles due to utility pole fires.
- Served as an expert witness evaluating impacts from airborne emissions associated with an oil spill into a river. The oil flowed downriver, and odors from the spill were noticed along the river. Ambient air monitoring data was available from soon after the spill occurred. Issues associated with this case included evaluating air monitoring data, and estimating volatilization, dispersion and chemical speciation of the emissions.
- Served as an expert witness in a litigation case where a release of mercaptans from a refinery was alleged to cause harm to students in a nearby school. The work involved analysis of samples to evaluate the composition of the released materials, an analysis of the release quantities, and the dispersion of those emissions.
- Provided impartial technical assistance to both the plaintiffs and defense in a toxic tort case involving aerosolized air emissions from a large acid manufacturing facility in Arkansas. Particular issues in the case surrounded the potential for particulate formation under certain meteorological conditions; evaluation of control technology, and overall evaluation of emissions from the facility.
- Provided expert assistance on a litigation case where subsurface methane gas from a rogue landfill was alleged to damage property values in a housing development. Developed methods to evaluate trace chemicals and extent of gas migration.
- Provided independent technical assistance to the court's mediator on landfill gas migration and control issues for a landfill toxic tort litigation involving a very large landfill (several square miles) in the Eastern United States.

Monitoring

- Project director for a community monitoring program in Richmond, California under California's AB 617. Richmond is an environmental justice community with large industrial sources, including a refinery and an acid plant, as well as heavily travelled freeways in its midst. The monitoring program included over 70 particulate and nitrogen dioxide monitors sited though a community outreach program. The monitoring was combined with a sophisticated modeling program incorporating real-time meteorology and traffic to yield hyper-localized air quality information including source attribution information.
- For a leading environmental non-governmental organization, prepared a white paper on the different types of inexpensive monitors that may be used to monitor emissions around oil and gas operations. We evaluated the scientific literature for monitor accuracy, stability and the potential for cross sensitivity to pollutants, and provided information on commercially available monitors, and also evaluated pre-commercialized monitoring options to determine what may be on the market in the short to medium term.
- Assisted in the design of a refinery monitoring plan in California. The monitoring was required as the result of a settlement with the host city as a result of a fire several years earlier. The refinery monitoring plan was intended to allow the community, on a real-time basis, to evaluate whether there were releases from the refinery, and included Fourier Transform Infra-Red (FTIR) monitors on the fenceline, along with fixed monitors for a variety of criteria pollutants and toxic air

contaminants. Our input was primarily designed to make the data more useful to the community and refiner.

- Directed a yearlong ambient air-monitoring program to measure particulate matter and diesel particulate matter (DPM) at the boundary of a large landfill in Los Angeles and a nearby school. The results of the monitoring program were analyzed temporally and as a function of meteorology. The results of the program showed that nearby freeways provided an overwhelming fraction of the measured DPM.
- Designed a complex fourteen-station ambient air monitoring network around a co-disposal landfill to measure the concentrations of 19 toxic chemicals in both gaseous and particulate phase for risk assessment purposes and negotiated approval with local, state and federal regulators.
- Analyzed the results of a complex multi-year total suspended particulate monitoring program to understand the sources of arsenic in the ambient air, and to evaluate the health risks of the arsenic levels that could be related to nearby facility emissions.
- Designed and conducted the compliance ambient air monitoring program for a large hazardous waste facility. The ongoing program collects whole air and total suspended particulate samples at five stationary sites. Prepared risk assessment based on the program, and quarterly reports for review by the local air district and the California Environmental Protection Agency's (EPA')s Department of Toxic Substances and Control (DTSC).
- Designed, negotiated and managed a novel cost-effective ambient air monitoring program that yielded real-time information on the health impacts of a site remediation. This study is the basis of a well-received paper.

Land Use Entitlement

- Project director for Phillips 66 Rodeo Renewed Environmental Impact Report project, which will result in the largest renewable fuels refinery in the United States. Ramboll prepared technical sections for review by the lead agency, including air quality, greenhouse gases, hazards and noise. Key issues included transportation, and the construction of new processing units at the refinery.
- Project director for the Chevron Renewal Project Revised Environmental Impact Report to allow a large capital project to proceed at the Chevron Richmond Refinery. The Revised EIR fulfilled the requirements of a court decision with specific focus on the Climate Change and Air Quality sections of the EIR. The revision of the Climate Change section described mitigation measures and quantification of the efficacy of those mitigation measures. The Air Quality section included a comprehensive estimate of emissions from the refinery under a range of operating scenarios and addressed a range of process alternatives in the refinery.
- Prepared comprehensive air quality analysis for two large municipal solid waste landfills in Southern California. Evaluation included impact of exhaust from non-road heavy equipment, dust from waste operations, and emissions from landfill gas escaping the collection system, and flares and turbines used to destroy the landfill gas. Projects included public testimony on results of analysis.
- Analyzed the impacts of potential accident scenarios prior to the construction of several new industrial facilities. The results of the analyses were used to make recommendations as to how to improve the safety and minimize the risks to the surrounding community.
- Project director for the development of the California Air Pollution Control Officer's Association (CAPCOA) manual on quantifying mitigation for a wide variety of carbon reduction measures that can be used for residential and commercial development.
- Project director for CalEEMod®, a new software package to estimate GHG, air toxics and criteria pollutant emissions from new development projects in California.
- Evaluated climate change impacts of dozens of new projects under CEQA and National Environmental Policy Act (NEPA). Specific types of projects include large, multi-use developments, landfill expansions, and transportation hubs.
- Provided innovative air quality services for entitlement activities, including evaluating the impacts of freeways on air quality, the estimation of emissions from complex industrial facilities, and the

impact on public health of those emissions. Provided testimony at public hearings in support of technical analyses.

Permitting and Enforcement

- Provided nationwide compliance assistance to six iron and steel mini-mills. Work conducted includes: preparation of Title V permit applications and supporting emissions estimates; preparation of PSD permits and associated emissions and dispersion modeling; evaluation of RACT controls for mini-mills.
- Managed PSD permit applications for two aluminum smelting facilities. This work included preparation of the emissions inventories, managing the Class I and Class II modeling effort, conducting the best available control technology (BACT) analysis, and preparing the technical document. She also negotiated permit conditions with the agencies, and assisted with cross-border discussions with other impacted agencies.
- Assisted a large landfill in Southern California respond to a series of Notices of Violation surrounding odor issues. Ramboll conducted computational fluid dynamic (CFD) modeling study to evaluate the sources of odors at the landfill, as well as to predict where odors might occur in the neighborhood and under what conditions. Ramboll also conducted a surrogate sampling study where it was found that ethanol was a surrogate for odors. Finally, Ramboll assisted in the negotiations which allowed the landfill to continue operations.
- Managed the preparation of an application for an Authority to Construct for a state-of-the-art hazardous waste treatment storage and disposal facility, which included a risk assessment for the project, and successfully negotiated permit conditions with state and local agencies. Currently working with facility and regulators to implement permit conditions.
- Worked as a technical advisor to the Imperial County Air Pollution Control District (ICAPCD) for the permitting of a rail-haul landfill. This landfill is proposed to be the largest landfill in the United States, and had monitoring, modeling, and enforceability issues associated with the permit. Of particular interest was a phased permitting approach that allowed the landfill operator to take advantage of newer technologies that could reduce emissions of criteria pollutants over time.
- Prepared and submitted several Federal Operating Permit Applications under Title V of the Clean Air Act for industrial facilities. Currently working on ongoing negotiation for permits.

Other

- Evaluated the transport of perfluorooctanoic acid (PFOA) in the air and in the ocean as a part of a large multiphase study being carried out by DuPont. The study resulted in a poster presentation at the American Geophysical Union and centered on how the chemical properties of PFOA impact its transport.
- Evaluated the potential contribution of airborne dioxin releases from a refinery to deposit within a defined boundary and contribute to measured dioxin concentrations in wastewater. Analysis included estimation of dioxin releases from a variety of units, including flares; selection of units most likely to contribute to dioxin deposition; selection of deposition modeling technique; and analysis of results.
- Managed the consequence analysis for several Risk Management and Prevention Programs (RMPP). Projects included scenarios with acids, toxic gases, and chemical reactions. Analysis involved using standard analytical tools as well as some state of the art tools.
- Prepared carbon footprints for facilities in a variety of industries, including landfills, large and small manufacturing operations, commercial developments, and municipal services; assisted in development of GHG minimization programs.
- Provided support to a large shipping company in evaluating the effectiveness of its emissions reduction programs; oversaw design of an automated database system to track fuel use and emissions reductions from a variety of innovative programs to improve reporting and streamline the program.

- Evaluated the potential of deposited arsenic-based pesticide to contaminate adjacent property. Transport pathways examined included wind-blown dust, surface water transport, and vehicle trackout.
- Conducted preliminary evaluation of whether patterns of measured lead in soil supported contention that lead resulted from airborne emissions from a lead emitting stack located at the site. Concluded that insufficient data was available for analysis.
- Designed a protocol for estimating the quantities of specific hazardous chemicals disposed of in California by region and waste type, and worked with the Department of Health Services to verify protocol.
- Gave lecture series on the harmonization of the State and Federal Risk Management Programs in California, and how to best implement the unified program.
- Prepared and negotiated a settlement proposal with regulators for a large facility which included new methods for calculation of organic emissions, additional controls on processes, and monitoring requirements.
- Gave an invited lecture series to senior environmental professionals in Mexico on the technical basis of the estimation of the impacts of sudden releases of toxic and flammable materials, in the wake of the Guadalajara explosions. Managed technical support team for large toxic tort litigation that involved estimating current and historical emissions from several large facilities, comparing and choosing appropriate meteorological data for the analysis dispersion modeling, mapping of impacts with respect to plaintiffs, and comparison with air quality guidelines and toxicological end points.
- Analyzed the particulate emissions from a basic chemicals processing plant containing over 90 separate sources, conducting a dispersion and culpability analysis, and evaluating the effectiveness of proposed and implemented source controls.

Prior to joining Ramboll, Shari held the following positions:

- Physical Sciences Officer, Bureau of Oceans and Environmental and Scientific Affairs, US Department of State
  - Developed and implemented a successful negotiation strategy for cooperative scientific projects with Japan and the Soviet Union.
  - Worked with Japan's Science and Technology Agency to initiate a Japanese funding organization for innovative international biotechnological studies.
- Staff Scientist, Alza Corporation
  - Led teams that created, designed, tested, and patented controlled release transdermal and osmotic pump drug delivery systems.
  - Studied the correlation between drug physical chemical data and dermal transport and absorption.
  - Designed and implemented systems to provide effective membrane thickness control in the manufacture of miniature osmotic pumps.
- Lecturer, Department of Chemical Engineering, Stanford University
  - Taught courses in Chemical Engineering Laboratory and Technical Speaking and Writing.

AWARDS AND HONORS

American Association for the Advancement of Sciences Diplomacy Fellow, 1987-1988

United States Department of State Meritorious Honor Award, March 1989

PROFESSIONAL AFFILIATIONS AND ACTIVITIES

Member, American Institute of Chemical Engineers

Member, Air & Waste Management Association

PATENTS

H.F. Sanders, Y.L. Cheng, D.J. Enscore, S.B. Libicki. Transdermal Drug Composition with Dual Permeation Enhancers. Patent Number: 4,820,720. April 11, 1989.

R.M. Gale, D.J. Enscore, D.E. Nedberge, M. Nelson, Y.L. Cheng, S.B. Libicki. Transdermal Administration of Progesterone, Estradiol Esters, and Mixtures Thereof. Patent Number: 4,788,062. November 29, 1988.

PUBLICATIONS & PRESENTATIONS

Oroumiyeh F, Akherati A, Yarwood G, Libicki S. 2023. Shair real-time air quality visualization and source apportionment: a novel approach for informed community engagement *(Air & Waste Management Association: Environmental Justice: From Policy to Practice, 2023)*. October.

Akherati, A, Yarwood, G, Morris, R. and Libicki, SB. 2023. Modeling can support real-time sensors to provide a community with timely, location specific air quality information: putting complex science in the hands of the community. The Magazine for Environmental Managers. A&WMA. January. April.

T. Bowie; E. Chadwick; R. Han; C. Libicki; S. Libicki; E. Lupoff. 2023. Community based Odor App: A Tool to Engage the Community in Solving Odor Problems. Proceedings of the Water Environment Federation. May.

Luongo, J. Bandoro, J. Richman, K and Libicki, SB. 2021. Advancing Source Apportionment Techniques at the Community Level: Air Rangers Case Study. The Magazine for Environmental Managers. A&WMA. January.

Vijayaraghavan, K., Libicki, S., Beardsley, R., Ojha, S. 2021. Modeling of Atmospheric Mercury Deposition in India. In: Shiva Nagendra, S.M., Schlink, U., Müller, A., Khare, M. (eds) Urban Air Quality Monitoring, Modelling and Human Exposure Assessment. Springer Transactions in Civil and Environmental Engineering. Springer, Singapore. https://doi.org/10.1007/978-981-15-5511-4_13

Libicki, S.B. 2019. "Using Dispersion Modeling and Monitoring as a Basis of Estimating Emissions from Refineries." Presented at the Refinery and Chemical Symposium. November.

Bandoro, J. T. Olevski, K. Richman, D. Hill, M. Dvorak, J. Luongo, S. B. Libicki, C. Emery, G. Yarwood. 2019. "Ramboll Shair: Integrating real-time sensor measurements and regional/local-scale models in Richmond, California." Presented at the Community Modeling and Analysis System. October.

Vijayaraghavan, K., S.B. Libicki, R. Beardsley, J. Jung, S. Ojha. 2018. "Modelling of Atmospheric Mercury Deposition in India." Published in "Urban Air Quality Monitoring, Modelling and Human Exposure Assessment." Springer Publishing.

Nambiar, M. and S.B. Libicki. 2018. "Residential Indoor Particulate Matter Monitoring: A Comparative Study of Two Low-Cost Sensor Technologies". Presented at Air & Waste Management Association Annual Conference. Hartford. CT. June.

Klug, S.E., K.L. Krieger, D.W. Weaver, M.T. Keinath, S.B. Libicki. 2012. "Quantifying Filtration Impacts on Indoor Exposure to Particulates." Presented at Air & Waste Management Association Conference and Exposition. June 19, 2012.

Bowie, T.; S.B. Libicki, K.L. Davis, C. Emery. 2011. "Strategies for Designing an Odor Monitoring Program for Municipal Solid Waste Landfills." Presented at Air & Waste Management Association Conference and Exposition. June 22, 2011.

Keinath, M.T. and S.B. Libicki. 2010. "Preventing GHG Leakage: Benchmarking Emissions to Design a Fair Cap and Trade System under AB32." Presented at the 2010 California Construction and Industrial Materials Association (CalCIMA) Education Conference. San Diego, CA. September.

Van de Griend, R., R.W. Andersen, S.B. Libicki, J. Ilisco, U. Senturk. 2009. Arsenic In Glass Highway Marking Beads. A&WMA's 102nd Annual Conference & Exhibition, Detroit, MI. June.

Hou, M., M.T. Keinath, C. Helvestine, S.B. Libicki. 2008. Predicting Human Exposure near Freeways: A Comparison of AERMOD and CAL3QHCR. AWMA Annual Conference, Portland, Oregon. June.

Weaver D.W., S.B. Libicki, K.L. Davis. 2008. VMT, GHG Reduction, and Planning: Looking Under the Hood. Presented at American Planning Association California Chapter (APACA) Conference. September 21-24.

Keinath, M.T. and S.B. Libicki. 2008. Local Sourcing for Green Building: How Homegrown Materials Can Reduce Your Carbon Footprint. California Construction & Industrial Materials Association (CalCIMA) Annual Conference. September.

DiBiase, M. and S.B. Libicki. 2008. Emissions and the Shipping Industry: Emission Reductions for Ocean-Going Vessels in California Air & Waste Management Association Conference. June.

Libicki, S.B., D. Weaver, and D. Kim. 2007. A Technical Approach to Addressing Climate Change in Environmental Impact Reports. 2007 Environmental Law Conference at Yosemite. Environmental Law Section of the State Bar of California. October.

Kemball-Cook, S.R. and S.B. Libicki. 2006. "Using surface drifter buoys to estimate oceanic transport of surfactants". Presented at the American Geophysical Union Ocean Sciences Meeting.

Libicki, S.B. 1999. When Good Data Goes Bad: What the Numbers Really Mean. American Bar Association Section of Environment, Energy and Resources 7th Section Fall Meeting, San Diego, California. October.

Libicki, S.B. and R. Van de Griend. 1996. RMPs, RMPPs and SB 1889: Consolidation of State and Federal Risk Management Programs. Presented as a Minimum Continuing Legal Education course at various law firms. San Francisco, California. November-December.

Stuart, A.L., S. Jain and S.B. Libicki. 1996. The Use of Long-Term Meteorological Information to Predict Impact Probabilities Resulting from Toxic Chemical Releases. PSA 96-International Topical Meeting on Probabilistic Safety Assessment. American Nuclear Society, Park City, Utah. October.

Libicki, S.B. 1995. The Use of Simplified Quantitative Risk Analysis in Risk Management Decisions at Small and Medium-Sized Process Plants. 88th Annual Air & Waste Management Association Annual Meeting, San Antonio. June.

Jain, S. and Libicki, S.B. 1995. Estimating the Additional Airborne Release Due to Heat of Reaction and Aerosolization When Strong Acids React With Water during a Release. Air & Waste Management Association Annual Meeting, San Antonio. June.

Libicki, S.B. 1994. Emergency Release Modeling: Software options and usage strategies. Southwest Safety Congress and Exposition. May.

Libicki, S.B. and R. van de Griend. 1994. Practical Compliance Strategies for Laboratory and Production: Ensuring Compliance from the Ground Up. Bio International '94. Toronto. May.

Libicki, S.B., A. Andersen and R. Scofield. 1994. The Use of Ambient Air Monitoring Data for the Evaluation of Risks due to Particulate-Borne Metals: A Case Study. California Mining Association Annual Meeting. April.

Libicki, S.B. and R. Scofield. 1993. Issues and Solutions in Air Toxics Source Impacted Ambient Air Monitoring for Use in Risk Assessment. Fourth Annual West Coast Regional Conference: Current Issues in Air Toxics. November.

Gates, L.J., S.B. Libicki, R. Scofield, and J. Wilhelmi. 1993. A flexible real-time ambient air monitoring program during Superfund Site redevelopment. EPA/AWMA Field Screening Methods for Hazardous wastes and Toxic Chemicals. February 24-26.

P.M. Salmon, S.B. Libicki, and C.R. Robertson. 1988. A theoretical investigation of convective transport in the hollow fiber reactor. Chemical Engineering Communications 66:221 248.

Libicki, S.B., P.M. Salmon, and C.R. Robertson. 1986. Measurement of inert gas permeabilities in compact bacterial cell aggregates using an annular reactor. Annals of the New York Academy of Sciences, Vol. IV; and Biochemical Engineering 469:145 151.

Karel, S., S. Libicki, and C.R. Robertson. 1985. The immobilization of whole cells: Engineering principles. Chemical Engineering Science 40(8):1321 1354.

Campbell, J.H., P. Peters, S.B. Libicki, M.L. Gregg, and J.E. Clarkson. 1981. Analysis of the operation of Occidental's modified in situ retort 6. In Fourteenth Oil Shale Symposium Proceedings, Golden, Colo.: Colorado School of Mines Press.

Campbell, J.H., J.H. Raley, F.H. Ackerman, W.A. Sandholtz, and S.B. Libicki. 1980. Investigation of critical parameters in modified in situ retorting. In Thirteenth Oil Shale Symposium Proceedings, Golden, Colo.: Colorado School of Mines Press

APPENDIX B
EXPERT TESTIMONY IN THE PAST FOUR YEARS

List of Testimony
2019 – 2023
Shari Beth Libicki, PhD

Year	Case Name	Venue	Case No.
2020	A.O.A., et al. V. Doe Run Resources Corp., et al.	United States District Court, Eastern District of Missouri Eastern Division	4:11-CV-00044-CDP
2021	Advocates For A Cleaner Tacoma, et al., v. Puget Sound Clean Air Agency; Puget Sound Energy, Inc.,	Before the Pollution Control Hearings Board, State of Washington	PCHB No. P19-087c
2021	A.O.A., et al. V. Doe Run Resources Corp., et al.	United States District Court, Eastern District of Missouri Eastern Division	4:11-CV-00044-CDP
2022	Los Angeles Unified School District, v. S&W Atlas Iron & Metal Co., Inc.; 10019 S. Alameda Llc; Gary Weisenberg; Matthew Weisenberg; et al.	United States District Court for the Central District of California	2:20-cv-05330- SB-SK
2023	Jordan, et al. v. Terumo BCT Sterilization Services, Inc., et al, Darnell v. Terumo BCT Sterilization Services, Inc., et al,	Colorado District Court, Jefferson County, Colorado	2020CV31457 2020CV31481

APPENDIX C
REFERENCES AND MATERIALS CONSIDERED

Allied Chemical Company. 1975. Environmental Information Allied Chemical Corporation Metropolis, Illinois Facility License No. Sub-256 Docket No. 40-392. June 17. HONSteward-0497728.

Allied Chemical Company. 1984. Environmental Impact Appraisal for Renewal of Source Material License No. SUB-256 Docket No. 40-3392. May. NRCADAMS071162.

Allied Chemical Company. UF_6 Facility Stack Emissions 1971 Data. May 11. HONSteward-0498420 – HONSteward-0498422.

Allied Signal, Inc. 1995. Environmental Assessment for Renewal of Source Material License SUB-256 Docket 40-3392. April 10. NRCADAMS071049.

Associated Press. 2010. Cited by WISE Uranium Project. April 20. Available at: https://www.wise-uranium.org/eopusec.html. Accessed November 16, 2023.

Auberle, W. 2023. An Analysis of the Atmospheric Transport and Impacts of Emissions from the Honeywell Specialty Materials Metropolis Works Facility, Metropolis, Illinois. September 22. [Also includes supporting production materials for main report and appendices]

Climate Data. Metropolis Climate. Available at: https://en.climate-data.org/north-america/united-states-of-america/illinois/metropolis-132997/. Accessed October 25, 2023.

Collum, B. 2017. 2 - Radiation, Nuclear Facilities, Woodhead Publishing. https://linkinghub.elsevier.com/retrieve/pii/B9780081019382000027. Accessed December 7, 2023.

Department of Energy (DOE). 2001. Transportation Impact Assessment for Shipment of Uranium Hexafluoride (UF 6) Cylinders from the East Tennessee Technology Park to the Portsmouth and Paducah Gaseous Diffusion Plants. Available at: https://www.nrc.gov/docs/ML1127/ML112720424.pdf. Accessed November 11, 2023.

DOE. 2007. Annual Site Environmental Report for Calendar Year 2005. Page 9-12. August. Available at: https://pubdocs.pad.pppo.gov/Annual%20Site%20Environmental%20Report%20%28ASER%29/2005%20ASER/2005%20ASER.pdf. Accessed November 16, 2023.

DOE. 1997. Paducah Site Annual Report For 1995. January. Available at: https://inis.iaea.org/collection/NCLCollectionStore/_Public/28/073/28073831.pdf. Accessed November 16, 2023.

DOE. 2017. 2017 Paducah Site Annual Site Environmental Report. September. Available at: https://www.energy.gov/sites/prod/files/2018/10/f56/2017-Paducah_ASER.pdf. Accessed November 11, 2023.

DOE. 2019. Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant. May. Available at: https://semspub.epa.gov/work/04/11133935.pdf. Accessed November 15, 2023.

Department of Justice (DOJ). 2016. Lockheed Martin Agrees To Pay $5 Million To Settle Alleged Violations Of The False Claims Act And The Resource Conservation And Recovery Act. Available at:

https://www.justice.gov/usao-wdky/pr/lockheed-martin-agrees-pay-5-million-settle-alleged-violations-false-claims-act-and. Accessed November 20, 2023.

Earth Resources Observation and Science (EROS) Center. 2003-2023. National Land Cover Database (NLCD) 2001-2021 Products, Data Release. Available at: https://www.mrlc.gov/viewer/. Accessed October 25, 2023.

EROS Center. 2018. National Land Cover Database. Available at: https://www.usgs.gov/centers/eros/science/national-land-cover-database. Accessed November 11, 2023.

Enercon Services, Inc. 2005. Environmental Report Renewal of Source Material License SUB-256 Docket No. 40-3392 for Honeywell Specialty Materials. May 25. HONSteward-0892794.

Enercon Services, Inc. 2017. Environmental Report: Renewal of Source Materials License SUB-526, Honeywell International, Inc., Metropolis Works, Metropolis, Illinois. February 8. NRCADAMS072853.

Environmental Protection Agency (EPA). 2013. Use of ASOS meteorological data in AERMOD dispersion modeling. Available at: https://www.epa.gov/sites/default/files/2020-10/documents/20130308_met_data_clarification.pdf. Accessed November 17, 2023.

EPA. 2017. 40 CFR Part 51, Appendix W Guideline on Air Quality Models. Vol. 82, No. 10. January 17. https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. Accessed November 10, 2023.

EPA. 2020. User's Guide for AERSURFACE Tool. EPA-454/B-20-008. February. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/related/aersurface/aersurface_ug_v20060.pdf. Accessed November 14, 2023.

EPA. 2023a. How does precipitation affect radiation levels in the environment? Available at: https://www.epa.gov/radnet/how-does-precipitation-affect-radiation-levels-environment . Accessed November 14, 2023.

EPA. 2023b. Superfund Site: Paducah Gaseous Diffusion Plant. Available at: https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.cleanup&id=0404794. Accessed November 15, 2023.

EPA. 2023c. User's Guide for the AMS/EPA Regulatory Model Section 3.3.2.1. October. Available at: https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod/aermod_userguide.pdf. Accessed November 14, 2023.

EPA. 2023d. What is a normal background exposure rate? Available at: https://www.epa.gov/radnet/what-normal-background-exposure-rate. Accessed November 13, 2023.

EPA. 2023e. What is background radiation? Is background radiation a risk to me and my family? Available at: https://www.epa.gov/radiation/what-background-radiation-background-radiation-risk-me-and-my-family. Accessed November 14, 2023.

Gabbard, A. 1993. Coal combustion: nuclear resource or danger. Oak Ridge National Laboratory Review. Vol. 26, No. 3&4. Available at: https://www.nrc.gov/docs/ML1002/ML100280691.pdf. Accessed November 11, 2023.

Giovinco.gov. 1996. Health and Safety: Environmental Oversight of Classified Federal Research (Testimony, 03/12/96, GAO/T-RCED-96-99). Available at: https://www.govinfo.gov/content/pkg/GAOREPORTS-T-RCED-96-99/html/GAOREPORTS-T-RCED-96-99.htm. Accessed November 20, 2023.

Haneberg, W. C. et al. A Geologically Based Indoor - Radon Potential Map of Kentucky. GeoHealth 2020, 4 (11), e2020GH000263. https://doi.org/10.1029/2020GH000263. Accessed December 7, 2023.

Herring, J.S. 2012. Uranium and Thorium Resources. In: Meyers, R.A. (eds) Encyclopedia of Sustainability Science and Technology. Springer, New York, NY. Available at: https://doi.org/10.1007/978-1-4419-0851-3_21. Accessed November 11, 2023.

Honeywell Metropolis Works. 1969 Monthly Operating Reports. HONSteward-0473987 - HONSteward-0474242.

Honeywell Metropolis Works. 1970 Monthly Operating Reports. HONSteward-0422073 - HONSteward-0422243.

Honeywell Metropolis Works. 1971 – 1980 Uranium Accountability Stack Losses. HONSteward-0224001 - HONSteward-0224036.

Honeywell Metropolis Works. 1978 Stack Emissions. HONSteward-0231476 - HONSteward-0231526.

Honeywell Metropolis Works. 1987 – 1998 Uranium Accountability Stack Losses. HONSteward-0502530 - HONSteward-0502622.

Honeywell Metropolis Works. Facility Effluent Reports. HONSteward-0225804 - HONSteward-0226060.

Honeywell Metropolis Works. 2004. Investigation Report of Uranium Hexafluoride Release on December 22, 2003. February 13. Available at: https://www.nrc.gov/docs/ML0526/ML052640427.pdf. Accessed November 14, 2023.

Honeywell Metropolis Works. 2009. NRC Effluent Report Calculations. HONSteward-0229606 - HONSteward-0229893.

Honeywell Metropolis Works. 2012. Mill Code Dump Report. HONSteward-0001289

Honeywell Metropolis Works. 2018a. Honeywell Metropolis Works "Ready Idle" Status. Available at: https://www.nrc.gov/docs/ML1802/ML18023A384.pdf. Accessed November 13, 2023.

Honeywell Metropolis Works. 2018b. Standard Operating Procedure – License Related Determination of Airborne Radioactivity. March 19. HONSteward-0070424.

GlobalSecurity.org. Honeywell Specialty Materials. Available at: https://www.globalsecurity.org/wmd/facility/metropolis.htm. Accessed December 7, 2023.

Huixia Wang, Barbara A Maher, Imad AM Ahmed, and Brian Davison. 2019. Efficient Removal of Ultrafine Particles from Diesel Exhaust by Selected Tree Species: Implications for Roadside Planting for Improving the Quality of Urban Air. Environmental Science & Technology 53 (12), 6906-6916 DOI: 10.1021/acs.est.8b06629

International Atomic Energy Agency. Depleted Uranium. Available at: https://www.iaea.org/topics/spent-fuel-management/depleted-uranium. Accessed November 2, 2023.

Litscheke, T. and Kuttler, W. 2008. "On the Reduction of Urban Particle Concentrations by Vegetation - a Review" Meterologishe Zeitschrift, 17 (3): 229-240. Available at: https://www.researchgate.net/publication/228352471_On_the_reduction_of_urban_particle_concentration_by_vegetation_-_A_review. Accessed December 7, 2023.

Maher, B. A.; Ahmed, I. A. M.; Davison, B.; Karloukovshi, V.; Clarke, R. 2013. "Impact of Roadside Tree Lines on Indoor Concentrations of Traffic-Derived Particulate Matter" Environmental Science and Technology, 47: 13737-13744. Available at: https://doi.org/10.1021/es404363m. Accessed December 7, 2023.

National Centers for Environmental Information. Global Hourly - Integrated Surface Database (ISD). Available at: https://www.ncei.noaa.gov/products/land-based-station/integrated-surface-database. Accessed November 10, 2023.National Oceanic and Atmospheric Administration (NOAA). 2022. NOAA/GSL Radiosonde Database. Available at: https://ruc.noaa.gov/raobs/. Accessed November 10, 2023.

Orano TLI. 2023. Services. Available at: http://tliusa.com/index.php/88-services. Accessed November 11, 2023.

Oregon Department of Environmental Quality. 2022. Recommended Procedures for Air Quality Dispersion Modeling. Available at: https://www.oregon.gov/deq/aq/cao/Documents/CAORP-AirQualityModeling.pdf. Accessed November 11, 2023.

Parviainen, A.; Loukola-Ruskeeniemi, K. Environmental Impact of Mineralised Black Shales. Earth-Science Reviews 2019, 192, 65–90. https://doi.org/10.1016/j.earscirev.2019.01.017. Accessed December 7, 2023.

Power Technology. 2021. Joppa Steam Power Plant, US. December 13. Available at: https://www.power-technology.com/marketdata/joppa-steam-power-plant-us/. Accessed November 11, 2023.

Power Technology. 2023. Power plant profile: Shawnee Fossil Plant, US. November 10. Available at: https://www.power-technology.com/data-insights/power-plant-profile-shawnee-fossil-plant-us/?cf-view. Accessed November 11, 2023.

Pugh, T. A. M.; MacKenzie, A. R.; Whyatt, J. D.; Hewitt, C. N. 2012. "The effectiveness of green infrastructure for improvement of air quality in urban street canyons" Environmental Science and

Technology, 46, 7692-7699. Available at: https://doi.org/10.1021/es300826w. Accessed December 7, 2023.

Schnug, E.; Lottermoser, B. G. Fertilizer-Derived Uranium and Its Threat to Human Health. Environ. Sci. Technol. 2013 , 47 (6), 2433–2434. https://doi.org/10.1021/es4002357. Accessed December 7, 2023.

Spalding, R. F.; Sackett, W. M. Uranium in Runoff from the Gulf of Mexico Distributive Province: Anomalous Concentrations. Science 1972 , 175 (4022), 629–631. https://doi.org/10.1126/science.175.4022.629. Accessed December 7, 2023.

Texas Commission on Environmental Quality. 2021. Howard County Monte Carlo Simulations. Available at: https://www.tceq.texas.gov/downloads/air-quality/sip/so2/howard/21010sip_howard_adsip_appendixl_pro.pdf. Accessed November 11, 2023.

Tuttle, M. L. W. et al. Weathering of the New Albany Shale, Kentucky: II. Redistribution of Minor and Trace Elements. Applied Geochemistry 2009 , 24 (8), 1565–1578. https://doi.org/10.1016/j.apgeochem.2009.04.034. Accessed December 7, 2023.

United Mine Workers of America (UMWA). 2023. Cook Coal Terminal – Local Union 2463. Available at: https://umwa.org/news-media/journal/cook-coal-terminal/. Accessed November 11, 2023.

Union Pacific. 2023. Cook Coal Terminal (American Electric Power). Available at: https://www.up.com/customers/bulk/ports-docks/cook/index.htm. Accessed November 11, 2023.

United States Nuclear Regulatory Commission (USNRC). 2021. Honeywell Metropolis Works – U. S. Nuclear Regulatory Commission Integrated Inspection Report Number 40-3392/2021-003. Available at: https://www.nrc.gov/docs/ML2129/ML21292A183.pdf. Accessed November 13, 2023.

USNRC. Footnotes for radionuclide tables in 10 CFR Part 20 Appendix B. Available at: https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/appb/footnotes.html. Accessed November 13, 2023.

United States Government Accountability Office. 2004. Nuclear Waste Cleanup: DOE Has Made Some Progress in Cleaning Up the Paducah Site, but Challenges Remain. April 1. Available at: https://www.gao.gov/products/gao-04-457. Accessed November 16, 2023.

United States Geological Survey (USGS). 1997. Radioactive Elements in Coal and Fly Ash: Abundance, Forms, and Environmental Significance. U.S. Geological Survey Fact Sheet FS-163-97. October. Available at: https://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.pdf. Accessed November 11, 2023.

USGS. 2001. Uranium and Radon in Ground Water in the Lower Illinois River Basin. Available at: https://pubs.usgs.gov/wri/2001/4056/wrir01_4056.pdf. Accessed November 11, 2023.

USGS. 2009. Thorium Deposits of the United States - Energy Resources for the Future? Available at: https://pubs.usgs.gov/circ/1336/pdf/C1336.pdf. Accessed November 11, 2023.

USGS. 2018. The National Elevation Dataset. Available at: https://www.usgs.gov/publications/national-elevation-dataset. Accessed November 11, 2023.

USGS. 2020. Hicks Dome Radiometric Data. Available at: https://www.sciencebase.gov/catalog/item/5e6c0b3fe4b01d5092638c95. Accessed November 11, 2023.

USGS. 2023. Coal Quality (COAL QUAL) Database. Available at: https://ncrdspublic.er.usgs.gov/coalqual/. Accessed November 11, 2023.

World Information Service on Energy (WISE) Uranium Project. 2021. Available at: https://www.wise-uranium.org/eopusec.html. Accessed November 16, 2023.

APPENDIX D
MTW LITIGATION SOIL DATABASE

(in separate electronic files)

APPENDIX E
MTW ENVIRONMENTAL LITIGATION DATABASE

(in separate electronic files)

APPENDIX F
MODELED URANIUM CONCENTRATION AND DEPOSITION AT PLAINTIFF LOCATIONS

Air Modeling Results at Plaintiff Locations					
UTM Coordinates (UTMx, UTMy)		Address	Period Average Uranium Concentration ($x10^{-14}$ µC/mL)	Maximum Annual Uranium Concentration ($x10^{-14}$ µC/mL)	Period Total Uranium Deposition (mg/m^2)
346,481.84	4,117,506.19	'1099 Country Club'	0.19	0.54	1.67
346,023.02	4,114,986.50	'2227 Hillcrest'	0.13	0.36	1.16
348,997.04	4,116,061.01	'32 East Lakeview'	0.06	0.18	0.56
349,749.00	4,113,808.76	'4 Woodhaven'	0.03	0.08	0.27
346,120.87	4,114,358.18	'509 West 20th'	0.11	0.32	1.01
346,039.37	4,114,355.46	'525 West 20th'	0.12	0.35	1.09
345,176.78	4,115,360.51	'20 Joshua'	0.32	0.84	2.91
345,051.38	4,115,028.08	'3 Triplett'	0.27	0.75	2.52
346,996.12	4,113,510.06	'313 East 12th'	0.06	0.18	0.57
344,947.80	4,116,728.77	'750 Airport'	0.39	1.07	3.51
346,749.90	4,113,433.62	'209 East 10th'	0.07	0.20	0.63
346,786.62	4,113,845.05	'108 East 15th'	0.07	0.21	0.65
345,168.00	4,115,129.15	'14 Grace'	0.26	0.70	2.37
341,769.97	4,120,404.14	'3110 Mick English'	0.05	0.12	0.42
348,985.70	4,117,491.71	'1247 Country Club'	0.08	0.23	0.71
345,042.86	4,116,373.97	'26 Neihoff'	0.47	1.28	4.26
344,968.84	4,117,316.18	'786 Airport'	0.30	0.84	2.70
345,046.41	4,116,427.07	'19 Neihoff'	0.45	1.23	4.10
341,029.63	4,122,803.33	'4191 Staton Ridge'	0.03	0.08	0.28
344,921.56	4,115,786.97	'690 Airport'	0.64	1.64	5.87
343,937.72	4,119,601.76	'3701 Carson'	0.09	0.25	0.84
345,754.27	4,114,847.02	'46 Adkins'	0.15	0.42	1.34
345,605.76	4,114,852.08	'49 Jon'	0.15	0.44	1.40
345,399.34	4,115,176.18	'71 Hospital'	0.23	0.64	2.12
344,390.99	4,115,858.69	'697 Mount Mission'	1.13	2.82	10.80

Notes:

Period used for average concentration and total deposition is 1971-2018.

All maximum concentrations occur in 1976.

APPENDIX G
MODELED URANIUM CONCENTRATION AND DEPOSITION AT NR-7

Modeled Results at NR-7 (post-1987 Location)		
UTM Coordinates 344323, 4115815 (m, NAD83, Zone 16)		
Year	Annual Average Uranium Concentration ($x10^{-14}$ µg/mL)	Annual Total Uranium Deposition (mg/m^2)
1971	0.93	0.19
1972	0.79	0.16
1973	0.70	0.14
1974	0.96	0.19
1975	0.92	0.18
1976	3.32	0.67
1977	2.72	0.55
1978	2.67	0.54
1979	2.43	0.49
1980	2.42	0.49
1981	2.28	0.46
1982	1.65	0.33
1983	2.15	0.43
1984	2.58	0.52
1985	1.71	0.34
1986	1.71	0.34
1987	0.83	0.17
1988	0.78	0.16
1989	0.56	0.11
1990	0.94	0.19
1991	0.91	0.18
1992	0.70	0.14
1993	0.93	0.18
1994	0.76	0.15
1995	0.99	0.20
1996	1.64	0.33
1997	1.61	0.32
1998	1.65	0.33
1999	2.14	0.43
2000	1.19	0.24
2001	1.18	0.24
2002	1.63	0.33
2003	0.97	0.20
2004	0.70	0.14
2005	1.13	0.23
2006	1.02	0.20

Modeled Results at NR-7 (post-1987 Location)		
UTM Coordinates 344323, 4115815 (m, NAD83, Zone 16)		
Year	**Annual Average Uranium Concentration ($x10^{-14}$ µg/mL)**	**Annual Total Uranium Deposition (mg/m^2)**
2007	1.31	0.26
2008	1.14	0.23
2009	1.42	0.28
2010	0.85	0.17
2011	0.83	0.16
2012	0.45	0.09
2013	0.63	0.13
2014	2.23	0.45
2015	1.40	0.28
2016	1.22	0.24
2017	0.52	0.10
2018	0.004	0.001
Period Average Concentration ($x10^{-14}$ µg/mL)	1.34	
Period Total Deposition (mg/m^2)		12.89

Notes:
Concentrations and depositions shown here are for the UTM listed in the table header, which is the location of NR-7 from 1987 onward.
The nearest residence was at a different location prior to 1987.